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OCT 9 1944

metal progress

annual reference issue

october 1944

● For many years Surface Combustion Industrial Furnace Engineers have been making heat treating history through the development and application of prepared atmospheres to established processes such as carburizing, hardening, normalizing, annealing, forging, etc. Today RX, DX, CG, NX and Char-Mo Gases are standard with metal processing and working industries.

During the past year announcements were made from the Surface Combustion Development Laboratory, of new advancements in the Science of Gas Chemistry and Heat Treating. To date these have included—

***Bright Gas Quenching, and**
Gas Pickling of Cold Rolled Steel

The application of Gas Chemistry to Heat Treating presents possibilities of tremendous importance to the metal working industry. The approach is basic—and, with a background of years of continuous heat treating research, Surface Combustion is an ideal reference source for your heat treating problems—*now and for the future.*

The Heat Treater's Helping Hand

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Standard and Special Industrial Furnace Equipment for: Forging, Normalizing, Annealing, Hardening, Drawing, Carburizing, Nitriding and Heating. Special Atmosphere Generators. *Write for bulletins.*

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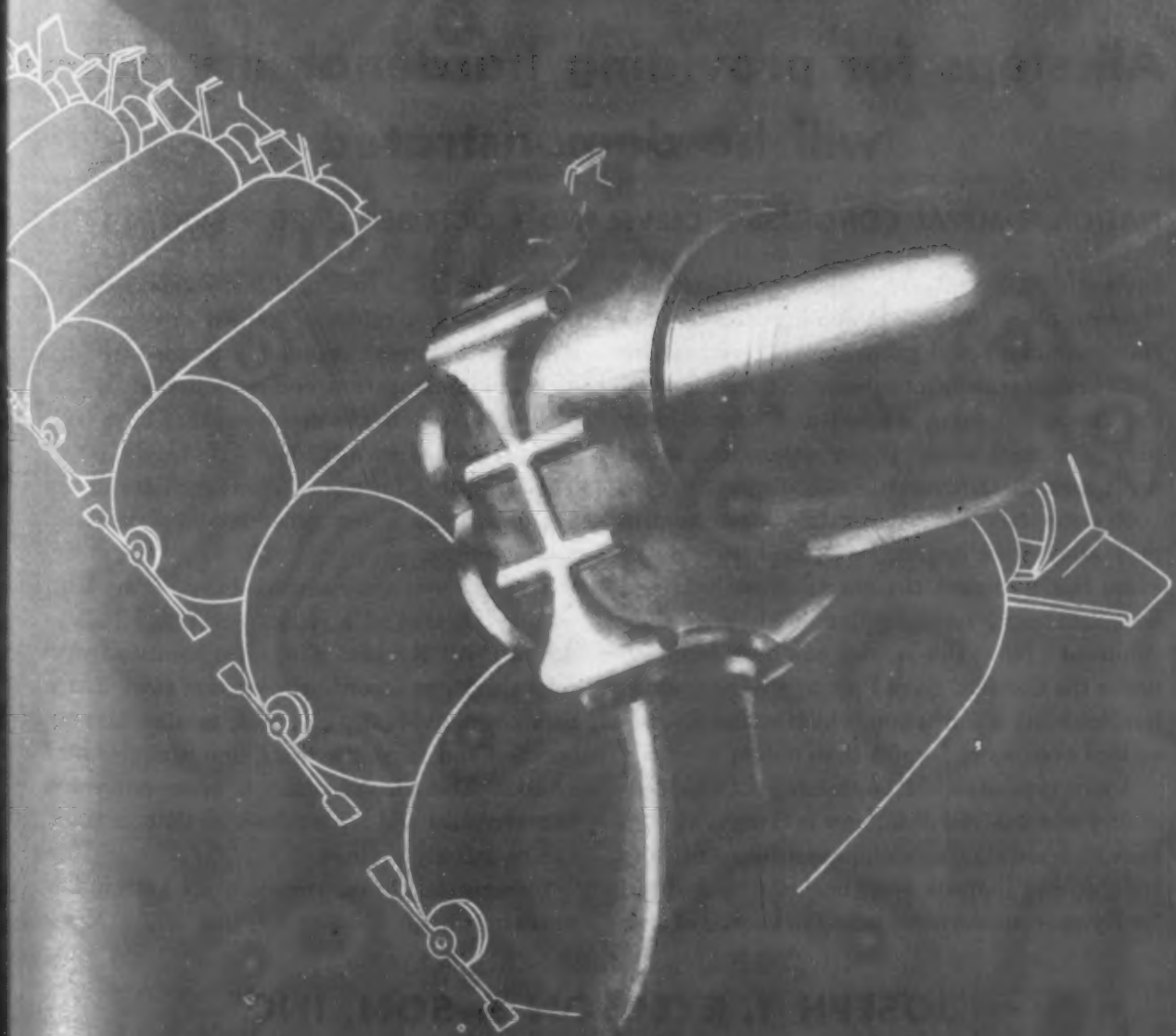
national metal congress



annual reference issue

october 1944

Ryerson Explains New Alloy Plan at Metal Show

All steps for providing hardenability data will be demonstrated

NATIONAL METAL CONGRESS • CLEVELAND • OCTOBER 16-20 • BOOTH 141-B

In Booth 141-B at the National Metal Congress, Ryerson plans to conduct Jominy End-Quench Hardenability Tests and to explain how hardenability results can be interpreted in terms of physical properties for quenched and drawn alloy bars of various sizes. If you attend the show, don't miss this unique Ryerson display.

Ryerson has always exercised close control over alloy steel quality, and for a number of years has furnished the chemical analysis and heat treatment response data with each alloy shipment. Now, this service has been extended under the Certified Steel Plan to give new added hardenability information, which makes Ryerson service even more helpful than before.

A new type of report, containing both hardenability and analysis data, now is being sent with each Ryerson alloy steel shipment. In addition to the chemical analysis, every heat of alloy destined for Ryerson stocks is subjected to a series of end-quench tests. The results of these tests are interpreted through tables of known physical relationships to reveal obtainable tensile strength, yield point, elongation, and reduction of area for bars up to 4 inches in diameter, that have been quenched and drawn at 1000°, 1100° and 1200° F. The Ryerson Alloy Steel Report includes all this test data plus a recommendation of working temperatures.

Whether you order a single bar or many tons, you are assured of a report covering all alloys shipped. All Ryerson alloys are identified with color markings according to type of steel. Large bars are individually stamped, smaller bars are bundled and tagged with an unmistakable heat symbol. The identification is cross referenced between steel and report sheet so that any steel can be quickly verified.

Investigate! Make sure you are getting this important help.

JOSEPH T. RYERSON & SON, INC.

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CONSOLIDATED PROGRAM

National Metal Congress

and War Conference Display

AMERICAN SOCIETY FOR METALS ⊜
AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS (A.I.M.E.)
AMERICAN WELDING SOCIETY (A.W.S.)
SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS (S.E.S.A.)
AMERICAN INDUSTRIAL RADIUM AND X-RAY SOCIETY (X-Ray)

Monday, Oct. 16, 1944

9:30 A.M. ⊜ Session on Surface Hardening; Hotel Statler

9:30 A.M. ⊜ Session on Hardenability; Hotel Statler

9:30 A.M. ⊜ Session on Non-Ferrous Metals; Hotel Statler

9:30 A.M. A.W.S. Opening Session on Welding Aids the War Effort; Presentation of Medals and Prizes; Hotel Cleveland

10:30 A.M. A.I.M.E. (Institute of Metals Division) Session on Magnesium; Hotel Statler

11:30 A.M. ⊜ Victory Session; Hotel Statler

12:00 M. War Conference Display opens; Public Auditorium

2:00 P.M. ⊜ Group Meeting on Metal Cutting and Tool Materials; Music Hall, Public Auditorium

2:00 P.M. ⊜ Group Meeting on Light Weight Construction, Ballroom, Public Auditorium

2:00 P.M. A.I.M.E. (Institute of Metals Division) Session on Grain Size of Magnesium; Hotel Statler

2:00 P.M. A.I.M.E. (Iron and Steel Division) General Session; Hotel Statler

2:00 P.M. A.W.S. Session on Welding and Cutting in Heavy Industries; Hotel Cleveland

2:00 P.M. A.W.S. Railroad and Transportation Session; Hotel Cleveland

2:00 P.M. A.W.S. Weldability Session; Hotel Cleveland

4:00 P.M. ⊜ Group Meeting on Surface Finishes and Protection; Music Hall, Public Auditorium

4:00 P.M. ⊜ Group Meeting on Sub-Zero Treatments; Ballroom, Public Auditorium

8:00 P.M. A.W.S. Adams Lecture; Hotel Cleveland

8:00 P.M. American Industrial Radium and X-Ray Society (Cleveland Section Regular Meeting); Hotel Hollenden

8:30 P.M. ⊜ Group Meeting on What's New in the Study of Corrosion; Music Hall, Public Auditorium

8:30 P.M. ⊜ Group Meeting on Induction Heating (Electronics in Overalls); Ballroom, Public Auditorium

10:30 P.M. War Conference Display closes

Tuesday, Oct. 17, 1944

9:30 A.M. ⊜ Session on Physical Properties; Hotel Statler

9:30 A.M. ⊜ Session on Hardenability; Hotel Statler

9:30 A.M. ⊜ Session on Aluminum and Magnesium Alloys; Hotel Statler

9:30 A.M. A.I.M.E. (Institute of Metals Division) Symposium on Creep of Non-Ferrous Metals and Alloys; Hotel Statler

9:30 A.M. A.W.S. Resistance Welding Session; Hotel Cleveland

9:30 A.M. A.W.S. Research Session; Hotel Cleveland

9:30 A.M. A.W.S. Structural Session; Hotel Cleveland

10:00 A.M. A.I.M.E. (Iron and Steel Division) General Session; Hotel Statler

10:00 A.M. S.E.S.A. Opening and Technical Session; Hotel Carter

11:30 A.M. ⊜ Victory Session; Hotel Statler

12:00 M. War Conference Display opens; Auditorium

12:30 P.M. A.I.M.E. (Iron and Steel Division) Executive Committee Luncheon and Business Meeting; Hotel Statler

2:00 P.M. ⊜ Group Meeting on the Hardenability Band as a Basis for Purchase and Use of Steel; Music Hall, Public Auditorium

2:00 P.M. ⊜ Group Meeting on Magnesium; Ballroom, Public Auditorium

2:00 P.M. A.I.M.E. (Institute of Metals Division) Symposium on Creep of Non-Ferrous Metals and Alloys; Hotel Statler

2:00 P.M. A.I.M.E. (Institute of Metals Division) Non-Ferrous Production Metallurgy; Hotel Statler

2:00 P.M. A.I.M.E. (Iron and Steel Division) Symposium on Recent Developments in Dilatrometric Analysis; Hotel Statler

2:00 P.M. A.W.S. Resistance Welding Session; Hotel Cleveland

2:00 P.M. A.W.S. Research Session; Hotel Cleveland

2:00 P.M. A.W.S. Session on Ships; Hotel Cleveland

2:00 P.M. Metal Powder Association Technical Session; Meeting Room A, Public Auditorium

2:30 P.M. S.E.S.A. Technical Session; Hotel Carter

4:00 P.M. ⊜ Group Meeting on Surface Peening to Increase Endurance; Music Hall, Public Auditorium

4:00 P.M. ⊜ Group Meeting on Instruments for Quality Control—A. Measurement of Linear Dimensions, Ballroom, Public Auditorium

6:00 P.M. A.I.M.E. Reception and Annual Fall Dinner, Metals Divisions; Hotel Statler

8:00 P.M. A.W.S. University Research Conference; Hotel Cleveland

8:30 P.M. ⊜ Group Meeting on National Emergency Steels and Hardenability Specification From the Consumer's Standpoint; Music Hall, Public Auditorium

8:30 P.M. ⊜ Group Meeting on Tin, Tin Alloys, Tin Coatings; Ballroom, Public Auditorium.

10:30 P.M. War Conference Display closes

Wednesday, Oct. 18, 1944

7:30 A.M. ⊜ Chapter Chairmen's Breakfast; Statler

8:30 A.M. Industrial Gas Breakfast and Round Table; Hotel Hollenden

9:30 A.M. ⊜ Annual Meeting; Hotel Statler

9:30 A.M. A.W.S. Session on Aircraft; Hotel Cleveland

9:30 A.M. A.W.S. Session on Research; Hotel Cleveland

9:30 A.M. Metal Powder Association Business Meeting; Hotel Statler

10:00 A.M. A.W.S. (Weldability Research Committee) Open Session; Hotel Cleveland

10:00 A.M. S.E.S.A. Symposium on Crankshaft Stresses; Hotel Carter

10:30 A.M. ⊜ Campbell Lecture; Hotel Statler

12:00 M. War Conference Display opens; Auditorium

12:00 M. ⊜ Canadian Luncheon; Hotel Statler

12:15 P.M. International Acetylene Association Annual Business Meeting and Luncheon; Hotel Statler

12:30 P.M. A.I.M.E. (Institute of Metals Division) Executive Committee Luncheon and Business Meeting; Hotel Statler

2:00 P.M. ⊜ Group Meeting on Metals for Railroads; Music Hall, Public Auditorium

2:00 P.M. ⊜ Group Meeting on New Trends in Metallurgical Heating; Ballroom, Public Auditorium

2:00 P.M. A.I.M.E. (Institute of Metals Division) General Session; Hotel Statler

2:00 P.M. A.I.M.E. (Iron and Steel Division) Symposium on Steelmaking; Hotel Statler

2:00 P.M. A.W.S. Session on Aircraft; Hotel Cleveland

2:00 P.M. A.W.S. Session on Machinery; Hotel Cleveland

2:00 P.M. A.W.S. Session on Piping and Pressure Vessels; Hotel Cleveland

2:30 P.M. S.E.S.A. Technical Session; Hotel Carter

4:00 P.M. ⊜ Group Meeting on Products From Metal Powders; Music Hall, Public Auditorium

4:00 P.M. ⊜ Group Meeting on Instruments for Quality Control—B. Means to Establish Identity; Ballroom, Public Auditorium

6:30 P.M. A.W.S. Section Officers Dinner and Conference; Hotel Cleveland

8:30 P.M. ⊜ Group Meeting on Manufacture of Quality Steels; Music Hall, Public Auditorium

8:30 P.M. ⊜ Group Meeting on Instruments for Quality Control—C. Detection and Measurement of Internal Defects; Ballroom, Public Auditorium

10:30 P.M. War Conference Display closes

Thursday, Oct. 19, 1944

9:30 A.M. ⊜ Session on Melting and Special Alloys; Hotel Statler

9:30 A.M. ⊜ Session on Toolsteel; Hotel Statler

9:30 A.M. ⊜ Session on Radiography and Testing; Hotel Statler

9:30 A.M. A.W.S. Foundry Session; Hotel Cleveland

9:30 A.M. A.W.S. Miscellaneous Session; Hotel Cleveland

10:00 A.M. X-Ray Technical Session; Hotel Hollenden

10:00 A.M. S.E.S.A. Technical Session; Hotel Carter

11:30 A.M. ⊜ Victory Session; Hotel Statler

12:00 M. War Conference Display opens; Public Auditorium

12:00 M. College Alumni Luncheons; Hotel Statler and Hotel Hollenden

12:00 M. Resistance Welders Manufacturers Association Monthly Business Meeting; Hotel Cleveland

12:30 P.M. A.I.M.E. (Iron and Steel Division) Physical Chemistry of Steelmaking Committee, Luncheon and Business Meeting; Hotel Statler

2:00 P.M. ⊜ Group Meeting on New Aluminum Alloys for Peacetime Uses; Music Hall, Public Auditorium

2:00 P.M. ⊜ Group Meeting on Salt Baths; Ballroom, Public Auditorium

2:00 P.M. A.W.S. Business Meeting; Hotel Cleveland

2:00 P.M. X-Ray Annual Meeting and Mehl Lecture; Hotel Hollenden

3:00 P.M. A.W.S. Board of Directors Meeting; Hotel Cleveland

4:00 P.M. ⊜ Group Meeting on Quality Control by Statistical Methods; Music Hall, Public Auditorium

4:00 P.M. ⊜ Group Meeting on Instruments for Quality Control—D. Atmosphere and Combustion; Ballroom, Public Auditorium

6:00 P.M. War Conference Display closes

6:30 P.M. S.E.S.A. Dinner; Hotel Carter

7:00 P.M. ⊜ Annual Dinner; Hotel Statler

Friday, Oct. 20, 1944

9:30 A.M. ⊜ Session on Chromium and Molybdenum Alloys; Hotel Statler

9:30 A.M. ⊜ Session on Fracture and Grain Size; Hotel Statler

9:30 A.M. ⊜ Session on Rolling and Graphitization; Hotel Statler

10:00 A.M. X-Ray Technical Session; Hotel Hollenden

10:00 A.M. S.E.S.A. Technical Session; Hotel Carter

11:30 A.M. ⊜ Victory Session; Hotel Statler

12:00 M. War Conference Display opens; Public Auditorium

2:00 P.M. ⊜ Group Meeting on Heat Treatment; Music Hall, Public Auditorium

2:00 P.M. ⊜ Group Meeting on Improved Gray Iron Castings; Ballroom, Public Auditorium

2:00 P.M. X-Ray Technical Session; Hotel Hollenden

2:30 P.M. S.E.S.A. Special Session on Electrical Strain Gage Techniques; Hotel Carter

10:30 P.M. National Metal Congress and War Conference Display ends.

Technical Meetings

All morning meetings are at the Hotel Statler, Cleveland

Simultaneous Morning Sessions

Monday, October 16

9:30 A.M. — Surface Hardening

LATTICE ROOM

Practical Aspects of the Selection of Frequency and Time for the Processing of Metallic Parts with Induction Heating
by *W. E. Benninghoff* and *H. B. Osborn, Jr.*, Ohio Crankshaft Co.

Induction Hardening of Plain Carbon Steels
by *D. L. Martin* and *F. E. Wiley*, General Electric Co.

Shot for Metal Peening
by *O. E. Harder* and *J. T. Gow*, Battelle Memorial Institute

9:30 A.M. — Hardenability

GRAND BALLROOM

Rates of Tempering in Cobalt Steels
by *E. A. Loria*, Carnegie-Illinois Steel Corp.

Isothermal Transformation and End-Quench Hardenability of Some NE Steels
by *R. L. Rickett*, *J. G. Cutton*, *C. B. Bernhart, Jr.* and *J. R. Millikin*, United States Steel Corp.

Further Developments of the End-Quench Hardenability Test
by *C. R. Wilks*, *Earnshaw Cook* and *Howard S. Avery*, American Brake Shoe Co.

A Hardenability Test for Low Carbon and Shallow Hardening Steels
by *O. W. McMullan*, Youngstown Sheet & Tube Co.

9:30 A.M. — Non-Ferrous Metals

SALLE MODERNE

A Survey of Wrought Magnesium Alloy Fabrication.
by *J. V. Winkler*, Dow Chemical Co.

The Copper-Manganese Equilibrium System
by *R. S. Dean*, *J. R. Long*, *T. R. Graham*, *E. V. Potter* and *E. T. Hayes*, U. S. Bureau of Mines

Properties of Transitional Structure in Copper-Manganese Alloys
by *R. S. Dean*, *E. V. Potter* and *J. R. Long*, U. S. Bureau of Mines

Age Hardening Copper-Manganese-Nickel Alloys
by *R. S. Dean*, *J. R. Long*, *T. R. Graham* and *C. W. Matthews*, U. S. Bureau of Mines

11:30 A.M. — Victory Session, by the Navy

GRAND BALLROOM

Tuesday, October 17

9:30 A.M. — Physical Properties

SALLE MODERNE

The Mechanism of Failure of 18 Cr, 8 Ni Cracking Still Tubes
by *C. L. Clark*, Timken Roller Bearing Co. and *J. W. Freeman*, University of Michigan

Capillarity of Metallic Surfaces
by *E. R. Parker*, University of California and *R. Smoluchowski*, General Electric Co.

The Effect of Fiber on Notched Bar Tensile Strength Properties of a Heat Treated Low Allow Steel
by *G. Sachs*, *J. D. Lubahn*, *L. J. Ebert* and *E. L. Aul*, Case School of Applied Science

The Effects of Notches of Varying Depth on the Strength of Heat Treated Low Allow Steels
by *G. Sachs*, *J. D. Lubahn* and *L. J. Ebert*, Case School of Applied Science

9:30 A.M. — Hardenability

LATTICE ROOM

The Effect of Carbon Content on Hardenability
by *E. S. Rowland*, *J. Welchner*, *R. G. Hill* and *J. J. Russ*, Timken Roller Bearing Co.

Air-Hardenability of Steels
by *C. B. Post*, *M. C. Fetzer* and *W. H. Fenstermacher*, Carpenter Steel Co.

The Partition of Molybdenum in Steel and Its Relation to Hardenability
by *Fred E. Bowman*, Climax Molybdenum Co.

The Rate of Diffusion of Molybdenum in Austenite and in Ferrite
by *John L. Ham*, Climax Molybdenum Co.

9:30 A.M. — Aluminum and Magnesium Alloys

GRAND BALLROOM

New Developments in High Strength Aluminum Alloy Products
by *E. H. Dix, Jr.*, Aluminum Co. of America

Aluminum Alloy Forging Materials and Design
by *L. W. Davis*, Aluminum Co. of America

The Properties of Aluminum Alloys Melted in an Induction Heated Crucible Furnace
by *James W. Poynter*, Army Air Forces, Wright Field

Magnesium Sheet
by *P. T. Stroup* and *G. F. Sager*, Aluminum Co. of America and *J. B. West*, American Magnesium Corp.

11:30 A.M. — Victory Session, by the Industry

GRAND BALLROOM

Technical Meetings

All morning meetings are at the Hotel Statler, Cleveland

9:30 A. M., Wednesday, October 18

Annual Meeting of the American Society for Metals
GRAND BALLROOM, HOTEL STATLER

1944 Edward de Mille Campbell Memorial Lecture
by *G. R. Fitterer*, University of Pittsburgh

Simultaneous Morning Sessions

Thursday, October 19

9:30 A.M. — Melting and Special Alloys

EUCLID BALLROOM

A Comparison of Aluminum and Titanium Deoxidation for Preventing Strain Aging Embrittlement in Low Carbon Steel
by *C. F. Comstock* and *J. R. Lewis*, Titanium Alloy Mfg. Co.

The Ar′ Reaction in Some Iron-Cobalt-Tungsten Alloys and the Same Modified With Chromium
by *W. P. Sykes*, General Electric Co.

The Basic Electric Melting Procedure for High Quality Alloy Steels
by *A. L. Ascik*, Sorel Industries, Ltd.

9:30 A.M. — Toolsteel

GRAND BALLROOM

The Dimensional Stability of Steel—Part I—Subatmospheric Transformation of Retained Austenite
by *S. G. Fletcher* and *Morris Cohen*, Massachusetts Institute of Technology

A Study of Subzero Treatments Applied to Molybdenum-Tungsten High Speed Steel
by *R. G. Kennedy, Jr.*, Cleveland Twist Drill Co.

Experiments of Sodium Cyaniding of High Speed Steel Prior to Hardening
by *John McIntyre*, International Business Machines Co.

9:30 A.M. — Radiography and Testing

LATTICE ROOM

A Comparison of Microhardness Indentation Tests
by *Douglas R. Tate*, National Bureau of Standards

Improved Sensitivity in Double Exposure Radiography
by *James Rigbey*, Ford Motor Co. of Canada

The Interpretation of Radiographs; Particularly Aircraft Parts
by *Leslie W. Ball*, Triplett & Barton, Inc.

11:30 A.M. — Victory Session, by the Ordance Dept.

GRAND BALLROOM

Friday, October 20

9:30 A.M.—Chromium and Molybdenum Alloys

EUCLID BALLROOM

Chromium Steels of Low Carbon Content
by *Russell Franks*, Union Carbide and Carbon Research Labs.

Characteristics and Properties of Some Cast Chromium-Molybdenum Steels
by *N. A. Ziegler* and *W. L. Meinhart*, Crane Co.

The Segregation of Molybdenum in Phosphorus Bearing Alloyed Gray Cast Iron
by *F. B. Rote*, Wyman-Gordon Co. and *W. P. Wood*, University of Michigan

9:30 A.M. — Fracture and Grain Size

GRAND BALLROOM

Fractography—A New Tool for Metallurgical Research
by *Carl A. Zapffe* and *Mason Clogg, Jr.*, Rustless Iron and Steel Corp.

Cleavage Structures of Iron-Silicon Alloys
by *Carl A. Zapffe* and *Mason Clogg, Jr.*, Rustless Iron and Steel Corp.

Grain Shape and Grain Growth
by *David Harker*, General Electric Co. and *Earl R. Parker*, University of California

Fracture Studies of Soldered Joints
by *F. Berman* and *R. H. Harrington*, General Electric Co.

9:30 A.M. — Rolling and Graphitization

LATTICE ROOM

Annealing Studies on Cold-Rolled Iron and Iron Binary Alloys
by *C. R. Austin*, *L. A. Luini* and *R. W. Lindsay*, Pennsylvania State College

The Effect of Cold Rolling on the Structure of Hadfield Manganese Steel
by *Norman P. Goss*, Cold Metal Products Co.

Factors Controlling Graphitization of Carbon Steels at Subcritical Temperatures
by *C. R. Austin*, Pennsylvania State College and *M. C. Fetzer*, Carpenter Steel Co.

11:30 A.M. — Victory Session, by the Air Forces

GRAND BALLROOM

Group Meetings & Discussions★

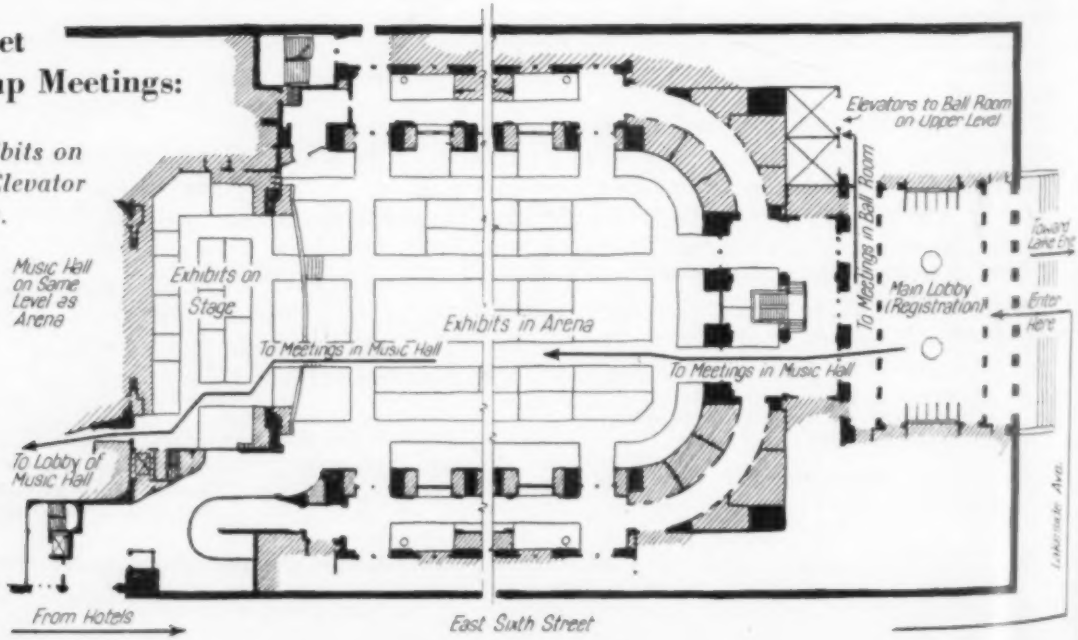
(Topics of the Times)

Monday October 16	*Tuesday October 17*	*Wednesday October 18*	*Thursday October 19*	*Friday October 20*
AFTERNOON MEETINGS AT 2:00 P.M. IN MUSIC HALL, CLEVELAND PUBLIC AUDITORIUM				
Metal Cutting and Tool Materials	The Hardenability Band as a Basis for Purchase and Use of Steel	Metals for Railroads	New Aluminum Alloys for Peace-Time Uses	Heat Treatment
AFTERNOON MEETINGS AT 2:00 P.M. IN BALL ROOM, CLEVELAND PUBLIC AUDITORIUM				
Light Weight Construction	Magnesium—Problems in Fabricating and Utilization	New Trends in Metallurgical Heating	Salt Baths	Improved Gray Iron Castings
AFTERNOON MEETINGS AT 4:00 P.M. IN MUSIC HALL, CLEVELAND PUBLIC AUDITORIUM				
Surface Finishes and Protection	Surface Peening to Increase Fatigue Resistance	Products From Metal Powders	Quality Control by Statistical Methods	
AFTERNOON MEETINGS AT 4:00 P.M. IN BALL ROOM, CLEVELAND PUBLIC AUDITORIUM				
Sub-Zero Treatments	Instruments for Quality Control; A—Measurement of Linear Dimensions	Instruments for Quality Control; B—Means to Establish Identity	Instruments for Quality Control; D—Measuring Devices for Atmosphere and Combustion	
EVENING MEETINGS AT 8:30 P.M. IN MUSIC HALL, CLEVELAND PUBLIC AUDITORIUM				
What's New in the Study of Corrosion (Round Table Discussion)	National Emergency Steels and Hardenability Specifications From the Consumer's Standpoint	Manufacture of Quality Steels		
EVENING MEETINGS AT 8:30 P.M. IN BALL ROOM, CLEVELAND PUBLIC AUDITORIUM				
Induction Heating (Electronics in Overalls)	Tin, Tin Alloys, Tin Coatings	Instruments for Quality Control; C—Detection and Measurement of Internal Defects		

★How to Get to the Group Meetings:

Through Exhibits on Stage and Elevator from Lobby.

Use The Map!


Elevators to Ball Room on Upper Level
To Meetings in Ball Room
Main Lobby (Registration)
Enter Here
Music Hall on Same Level as Arena
Exhibits on Stage
Exhibits in Arena
To Meetings in Music Hall
To Meetings in Music Hall
To Lobby of Music Hall
From Hotels
East Sixth Street

Society for Experimental Stress Analysis

All Meetings at Hotel Carter, Cleveland

Tuesday, October 17

10:00 A.M. — Technical Session

GRAND BALLROOM, HOTEL CARTER

Shot Peening to Improve Fatigue Resistance
by *O. J. Horger* and *H. R. Neifert*, The Timken Roller Bearing Co.

Plastic-Flow Problems by Photo-Grid Methods
by *J. F. Harding* and *C. P. O'Haven*, Armour Research Foundation

Load Distribution in Riveted and Spot-Welded Joints
by *M. Goland* and *L. D. Morris*, Curtiss-Wright Corp.

2:30 P.M. — Technical Session

GRAND BALLROOM, HOTEL CARTER

Residual Stress Studies of Life Improving Surface Treatments
by *R. W. Greaves*, *E. C. Kirstowsky* and *C. Lipson*, Chrysler Corp.

New Approaches to Engineering Design
by *E. E. Stilson*, *R. H. Peterson* and *R. C. Pocock*, Bendix Aviation Corp.

Wednesday, October 18

10:00 A.M. — Symposium on Crankshaft Stresses

GRAND BALLROOM, HOTEL CARTER

Structural Evolution of a Crankshaft
by *S. Oldberg* and *C. Lipson*, Chrysler Corp.

Determination of Operating Loads and Stresses in Crankshafts
by *A. Goloff*, Caterpillar Tractor Co.

Metallurgical Processing of Packard Built Rolls-Royce Crankshafts
by *M. L. Frey*, Packard Motor Car Co.

2:30 P.M. — Symposium on Crankshaft Stresses

GRAND BALLROOM, HOTEL CARTER

Full Scale Fatigue Testing of Crankshafts
by *C. W. Gadd* and *N. A. Ochiltree*, General Motors Research Laboratories

Determining Crankshaft Durability for Increased Performance of In-Line Engine
by *W. Osborn*, Sterling Engine Co.

Thursday, October 19

10:00 A.M. — Technical Session

GRAND BALLROOM, HOTEL CARTER

The Application of Stress Models to Specific Structural Problems
by *S. F. Tingley*, Goodyear Aircraft Corp.

Electrical Analogy for Shear Lag Problems
by *R. E. Newton*, Curtiss-Wright Corp.

Electric Method for the Solution of Laplace's Equation
by *V. Paschkis*, Columbia University

6:30 P.M. — Annual Dinner

GRAND BALLROOM, HOTEL CARTER

Friday, October 20

10:00 A.M. — Technical Session

GRAND BALLROOM, HOTEL CARTER

Precision Determination of Weight by Means of Bonded Strain Gages
by *A. L. Thurston*, Cox & Stevens Aircraft Corp. and *R. W. Cushman*, The Foxboro Co.

The Magnetic Coupled-Torque Meter
by *B. F. Langer*, Westinghouse Research Laboratories

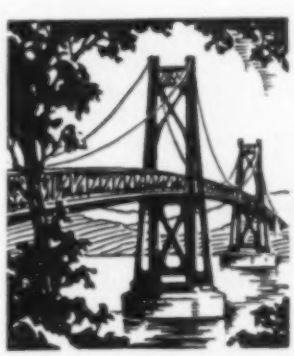
Impact Stress Analysis by Brittle Coatings
by *G. Ellis*, Magnaflux Corp.

2:30 P.M. — Electrical Strain Gage Techniques

GRAND BALLROOM, HOTEL CARTER

Electric Gaging Systems: Their Selection and Application
by *H. C. Robert*, University of Illinois

Open Forum for Discussion on Characteristics of Amplifiers, Characteristics of Galvanometers, Calibration Circuits, Methods of Recording, Use of Crystals in Stress Analysis, and Additional Topics Put Forward by the Audience



American Institute of
Mining and Metallurgical Engineers

Iron and Steel Division

Monday, October 16

2:00 P.M. — General Session

PINE ROOM, HOTEL STATLER

Recovery of Cold Worked Aluminum-Iron as Detected by Changes in Magnetic Properties
by *J. S. Stanley*, Westinghouse Electric and Mfg. Co.

Distribution of Carbon Between Titanium and Iron in Steels
by *W. P. Fishel* and *Bryson Robertson*, Vanderbilt University

Transformation of Austenite in a 3% Chromium, 1% Carbon Steel
by *E. P. Klier*, Pennsylvania State College

Tuesday, October 17

10:00 A.M. — General Session

PINE ROOM, HOTEL STATLER

A Test for Hydrogen Embrittlement and Its Application to 17% Cr, 1% C Stainless Steel Wire
by *C. A. Zapffe* and *M. Eleanor Haslein*, Rustless Iron and Steel Corp.

Effect of Time Storage on Ductility of Welded Test Specimens
by *C. E. Jackson* and *G. G. Luther*, Naval Research Laboratory

12:30 P.M.—Luncheon and Business Meeting of Executive Committee

2:00 P.M. — Symposium on Recent Developments in Dilatometric Analysis

PINE ROOM, HOTEL STATLER

Dilatometric Analysis of Sub-Atmospheric Transformations
by *R. D. Potter*, Massachusetts Institute of Technology

A High-Speed Dilatometer and the Transformational Behavior of Six Steels
by *A. L. Christiansen*, *E. C. Nelson* and *C. E. Jackson*, Naval Research Laboratory

Dilatometric Studies on the Growth of Gray Cast Iron by *N. A. Ziegler*, Crane Co.

Precise Expansion Measurements on Non-Ferrous Alloys and Glasses
by *W. E. Kingston*, Sylvania Electric Products, Inc.

An Interference Type Dilatometer and Some typical Results
by *W. L. Fink* and *L. A. Willey*, Aluminum Co. of America

6:00 P.M. — Reception and Annual Fall Dinner of the Metals Divisions

EUCLID ROOM, HOTEL STATLER

Wednesday, October 18

2:00 P.M. — Symposium on Steelmaking

EUCLID ROOM, HOTEL STATLER

Theoretical and Practical Aspects of Deoxidation in Basic Openhearth Practice
by *T. S. Washburn*, Inland Steel Co.

Slag-Metal-Oxygen Relationships in the Basic Openhearth and Electric Processes
by *J. S. Marsh*, Bethlehem Steel Co.

A Rapid Laboratory Method for Estimating Basicity of Openhearth Slag
by *W. O. Philbrook*, *A. H. Jolly, Jr.* and *T. R. Henry*, Wisconsin Steel Works

Application of pH Slag Basicity Measurements to Basic Openhearth Phosphorus Control
by *Michael Tenenbaum* and *C. C. Brown*, Inland Steel Co.

Thursday, October 19

12:30 P.M. — Luncheon and Business Meeting, Committee on Physical Chemistry of Steel Making

Institute of Metals Division

Monday, October 16

10:30 A.M. — Magnesium

PINE ROOM, HOTEL STATLER

The Relationship Between Magnesium Core Sand Mixtures and the Burning of Magnesium
by *O. J. Myers*, Wright Aeronautical Co.

Solubility of Manganese in Magnesium
by *N. Tiner*, Permanente Metals Corp.

2:00 P.M. — Grain Size of Magnesium

EUCLID ROOM, HOTEL STATLER

Grain Size and Properties of Sand Cast Magnesium Alloys
by *R. S. Busk* and *C. W. Phillips*, Dow Chemical Co.

Factors Affecting Abnormal Grain Growth of Magnesium Alloy Castings
by *A. T. Peters*, *R. S. Busk* and *H. E. Elliott*, Dow Chemical Co.

Grain Size of Sand Cast Magnesium Alloys
by *Oscar Blohm*, Hills-McCanna Co.

Institute of Metals Program continued on next page . . .

Program of the Institute of Metals Division (Continued)

Tuesday, October 17

9:30 A.M. and 2:00 P.M. — Symposium on Creep of Non-Ferrous Metals and Alloys

EUCLID ROOM, HOTEL STATLER

Application of Non-Ferrous Alloys in Stress Design
by *J. J. Kanter*, Crane Co.

Creep Test Methods and the Interpretation of Creep Data
by *P. G. McVetty*, Westinghouse Electric and Mfg. Co.

Creep Characteristics of a Phosphorized Copper
by *N. L. Burghoff* and *A. I. Blank*, Chase Brass and Copper Co.

Creep Properties of Cold Drawn Annealed "B" Monel and Inconel
by *B. B. Betty*, *H. L. Eiselstein* and *F. P. Huston, Jr.*, International Nickel Co.

Notes on the Elevated Temperature Properties of Some Cast Copper-Base Alloys
by *H. E. Montgomery*, The Lunkenheimer Co.

Creep Data on Die Cast Zinc Alloy
by *E. H. Kelton* and *B. B. Grissinger*, New Jersey Zinc Co.

Creep Properties of Some Rolled Lead Alloys
by *A. A. Smith, Jr.*, American Smelting and Refining Co.

2:00 P.M. — Non-Ferrous Production Metallurgy

LATTICE ROOM, HOTEL STATLER

Tin Smelting and Metallurgy
by *C. L. Mantell*, Consultant Chemical Engineer

Beryllium by *Donald M. Liddell*, Consulting Engineer

Antimony: Its Metallurgy and Refining
by *Chung Yu Wang*, Wah Chang Trading Corp. and *Guy C. Riddell*, Consulting Mining Engineer

Modern Quicksilver Reduction Plants
by *G. I. Gould*, H. W. Gould & Co.

6:00 P.M. — Reception and Annual Fall Dinner of the Metals Divisions

EUCLID ROOM, HOTEL STATLER

Wednesday, October 18

2:00 P.M. — General Session

PINE ROOM, HOTEL STATLER

Orientation Structure on the Surface of Cast Metals
by *Gerald Edmunds*, New Jersey Zinc Co.

The Hardness of Silver-Antimony Solid Solutions
by *R. M. Treco* and *J. H. Frye, Jr.*, Lehigh University

Substitute Solders of the 85-15 Lead-Tin Type
by *James B. Russell* and *J. O. Mack*, Naval Research Laboratory

American Industrial Radium and X-Ray Society

All Meetings in Ballroom, Hollenden Hotel, Cleveland

Thursday, October 19

10:00 A.M. — Technical Session

Automatic Film Processing and Equipment
by *Robert Sarderson*

X-Ray and Welding Control by *John J. Chyle*

A Practical Comparison of Fluoroscopy with Radiography by *Robert Mayer*

Filtration by *Don M. McCutcheon*, Ford Motor Co.

2:00 P.M. — Annual Meeting; Mehl Lecture

Election of Officers

Address by Retiring President
Maynard B. Evans, Jr., Ternstedt Mfg. Division, General Motors Corp.

Experimental Stress Analysis in Radiographically Sound Materials
by *George L. Clark*, University of Illinois

Presentation of Mehl Lecture Award
by *M. B. Evans*

Friday, October 20

10:00 A.M. — Technical Session

Quality Control of Radiographs by a Direct Density Check by *Alvin F. Cota*

A Simplified Method of Film Evaluation
by *Emery Meschter*

Method of Determining Metal Thickness Radiographically
by *H. P. Moyer* and *P. L. Kline*

Three Dimensional Radiography by *Douglas Wineck*

2:00 P.M.—Technical Session

Requirements in Specifications for Uniform Radiographic Technique by *George A. Russ*

The Use of Static Tests as a Method of Determining the Radiographic Classification of Castings
by *F. S. Wyle*

An Example of Electron Images in Million Volt Radiography by *Al Morris*

The Three Functions of the Radiographic Interpreter
by *Leslie W. Ball*

American Welding Society Program

All meetings are at Hotel Cleveland, Public Square

Monday, October 16

9:30 A.M. — Welding Aids the War Effort

Presentation of Medals and Prizes

Welding as an Aid in Shipbuilding Construction
by *Admiral H. L. Vickery*, U. S. Maritime Commission

Welding as an Aid in the Fabrication of Ordnance Equipment
by *Col. S. B. Ritchie*, Office, Chief of Ordnance

2:00 P.M. — Welding and Cutting in Heavy Industries

Fundamentals of Heavy Cutting
by *G. L. Walker* and *H. G. Hughey*, Air Reduction Sales Co.

Fabrication and Reclamation in Steel Mill Maintenance
by *E. W. Gruber*, Wheeling Steel Corp.

Unusual Applications of Gas Cutting in Ordnance Fabrication
by *C. M. Underwood*, Northern Ordnance, Inc.

Procedure Control of Automatic Welding Processes
by *A. E. Bedell* and *J. B. Quigley*, Graver Tank & Mfg. Co., Inc.

2:00 P.M. — Railroad and Transportation

Welding of Aluminum Tank Cars
by *A. H. Woollen*, Railroad Sales, Aluminum Co. of America

Welding for Main Line Operation
by *O. K. Kjolseth*, General Electric Co.

Railroad Welding
by *John McMullen*, Erie R. R.

2:00 P.M. — Weldability

Welding of Manganese Steels
by *W. B. Brooks* and *A. G. Waggoner*, Cramp Shipbuilding Co.

High Tensile Manganese-Silicon Steels for Welded Fabrication
by *G. G. Luther* and *F. H. Laxar*, Naval Research Laboratory

The Bead-Weld Nick-Bend Test for Ductility
by *C. E. Jackson* and *G. G. Luther*, Naval Research Laboratory

The Influence of Minor Variables of Weldability
by *R. D. Stout*, *S. S. Tor* and *G. E. Doan*, Lehigh University

8:00 P.M. — Adams' Lecture

Solid Phase Welding
by *A. B. Kinzel*, Union Carbide & Carbon Corp.

Tuesday, October 17

9:30 A.M. — Resistance Welding

Spot Welding Machines for Heavy Gauges of Ferrous and Non-Ferrous Metals
by *Mario Sciaky*, Sciaky Bros.

Heat Transfer Across Contact Surfaces
by *W. B. Kouwenhoven*, Johns Hopkins University

Problems in Spot Welding Heavy Mild Steel Plate
by *F. R. Hensel*, *E. I. Larsen* and *E. F. Holt*, P. R. Mallory & Co., Inc.

9:30 A.M. — Research

The Effect of Postheating in Welding Alloy Steels
by *M. A. Pugacz* and *G. J. Siegel*, Naval Research Laboratory

Stress Relieving Study
by *Prof. J. R. Stitt*, Ohio State University

The Effects of Heat Treatment Upon the Fatigue Strength of Carbon-Steel Plates
by *W. H. Bruckner* and *W. H. Munse*, University of Illinois

9:30 A.M. — Structural Welding

Standard Details for Welded Building Construction
by *H. W. Lawson*, Bethlehem Steel Co.

Field Welded Pressure and Variable Volume Storage Tanks
by *Fred L. Plummer*, Hammond Iron Works

Welding Railroad Structures
by *T. H. Gardner*, Florida East Coast Railway

2:00 P.M. — Resistance Welding

Low Reactance Cable for Portable Resistance Welders
by *Myron Zucker*, Mackworth G. Rees, Inc.

The Flash Welding of Alloy Steels—Welding Techniques and Variables
by *J. J. Riley*, Taylor-Winfield Corp.

Metallurgical and Physical Characteristics of Flash Welded Alloy Steels
by *J. C. Barrett*, Taylor-Winfield Corp.

Small Portable Condenser Welding Set
by *E. M. Callender*, E. G. Budd Mfg. Co.

2:00 P.M. — Research

Some Recent Developments in Stainless Steel Welding
by *D. L. Mathias*, Metal & Thermit Corp.

Bi-axial Fatigue Strength of Low-Carbon Steels
by *George K. Morikawa* and *LeVan Griffis*, Illinois Institute of Technology

Weldability Tests of Cast Steel
by *C. E. Jackson* and *F. S. McKenna*, Naval Research Lab.

Weldability—as-Rolled vs. Heat-Treated High Strength Constructional Steels
by *Lt. S. A. Herres* and *W. L. Warner*, Watertown Arsenal

American Welding Society Program

Tuesday, October 17

Afternoon Program, Continued

2:00 P.M. — Welded Ships

Controls Required for Safe and Economical Construction of Welded Ships
by *D. G. Maxson*, Welding Consultant, Marinship Corp.

Technical Control of Welding in Ship Construction
by *M. H. MacKusick*, California Shipbuilding Corp.

Evolution of Welding in Shipbuilding
by *M. N. Maltseff*, Western Pipe and Steel Co.

Multiple and Stack Machine Cutting
by *A. H. Yoch*, Air Reduction Sales Co.

8:00 P.M. — University Research Conference

Wednesday, October 18

9:30 A.M. — Aircraft Welding

Impact Strength of Arc Welded Joints in Aircraft Steel
by *H. O. Klinke*, Republic Aviation Corp.

Helium Shielded Arc Welding of Stainless Steel Exhaust Collectors
by *Francis H. Stevenson*, Lockheed Aircraft Corp.

Multi-Arc Welding of Aluminum Alloys
by *M. R. Rivenburgh* and *C. W. Steward*, Curtiss-Wright Corp.

9:30 A.M. — Research

Intergranular Corrosion of Stainless Steel Welds
by *Wm. T. Tiffin*, University of Oklahoma

The Effect of Time and Temperature on the Relief of Residual Stresses in Low Alloy Steels
by *J. K. McDowell* and *Lt. Col. Paul C. Cunnick*, Rock Island Arsenal

Development and Application of Modern Heavy Coated Arc Welding Electrodes
by *D. C. Smith* and *W. G. Rinehart*, Harnischfeger Corp.

10:00 A.M.— Open Session, Weldability Research Committee

The Tee-Bend Energy Weldability Test
by *Leon C. Bibber*, Carnegie-Illinois Steel Corp.
and *Julius Heuschkel*, Westinghouse Electric & Mfg. Co.

2:00 P.M. — Aircraft Welding

The Geometry of a Spot Welding Tip and Its Relation to Tip Life
by *E. D. Crawford* and *C. W. Steward*, Curtiss-Wright Corp.

Survey of Chemical Cleaning Practices for Spot Welding Aluminum Alloys
by *F. M. Morris*, Kaiser Cargo, Inc., Fleetwings Div.

An Evaluation of Process Control of Aircraft Welding
by *P. H. Merriman*, The Glenn L. Martin Co.

Characteristics of Welding Arcs on Aluminum in Atmospheres of Helium and Argon
by *F. A. Wassell*, General Electric Co.

Wednesday, October 18

Afternoon Program, Continued

2:00 P.M. — Welding of Machinery

Production Problems and Production Control
by *E. C. Brekelbaum*, Harnischfeger Corp.

Routine Inspection and Salvage of Machinery Weldments — Rough, Partially Machined and Machined
by *James W. Owens*, Fairbanks, Morse & Co.

Welded Jigs and Fixtures
by *A. N. Kugler*, Air Reduction Sales Co.

Design of Welded Machinery
by *John Mikulak*, Electric Machinery Manufacturing Co.

2:00 P.M. — Piping and Pressure Vessels

Pressure Vessel Welding
by *Edward B. McGuire*, Hamler Boiler & Tank Co

Normalizing of Welds in Carbon-Molybdenum Steel Pipe by 60-Cycle Induction Heating
by *I. A. Rohrig* and *D. H. Corey*, The Detroit Edison Co.

Properties of Welded Joints Between Dissimilar Metals
by *E. C. Chapman* and *R. E. Lorentz*, Combustion Engineering Co.

Oxy-Acetylene Pressure Welding
by *A. R. Lytle*, Union Carbide & Carbon Res. Labs.

6:30 P.M.—Section Officers Dinner and Conference

Thursday, October 19

9:30 A.M. — Foundry Cutting and Welding

Arc Welding Practices in the Steel Foundry
by *Frank Kiper* and *Lawrence Gales*, Ohio Steel Foundry

Machine Cutting of Risers, Flame Scarfing to Remove Padding, and Flame Gouging to Remove Webs and Defects
by *G. E. Bellew*, Air Reduction Sales Co.

Repair of Castings
by *L. A. Danse*, Chairman, Metallurgical Committee, General Motors Corp.

9:30 A.M. — Miscellaneous Topics

Low Temperature Joining
by *R. D. Wasserman* and *C. E. Swift*, Eutectic Welding Alloys Co.

How Much Ductility Is Necessary for a Structure or Machine?
by *W. J. Conley*, Lincoln Electric Co.

2:00 P.M. — Business Meeting, A.W.S.

3:00 P.M. — Board of Directors Meeting

Roster of ASM Chapters

Chapter	Chairman	Secretary	Secretary's Address	Monthly Meeting
Baltimore	C. G. Stephens	Nelson A. Pyle	Revere Copper & Brass, 1301 Wicomico St.	Third Monday
Birmingham	R. S. Crowder	Joseph P. Flood	1516 N. 23rd St., Apt. B-6	—
Boston	J. T. Norton	H. E. Handy	Saco-Lowell Shops, Biddeford, Maine	First Friday
British Columbia	R. G. Smith	J. R. Morris	Dendoff Springs, Ltd., Vancouver, B. C.	Third Thursday
Buffalo	George B. Michie	J. H. Birdsong	Buffalo Testing Labs., 37 Niagara St.	Second Thursday
Calumet	H. H. Feierabend	I. N. Goff	3761 Polk St., Gary, Ind.	Second Tuesday
Canton-Massillon	D. C. Ladd	L. A. Zeitz	East Ohio Gas Co., Canton, Ohio	—
Chicago	J. Walter Scott	L. J. Bohan	80 E. Jackson Blvd.	Second Thursday
Cincinnati	W. W. Petry	A. P. Fischer	E. F. Houghton & Co.	Second Thursday
Cleveland	W. Naujoks	Warren A. Silliman	Cleveland Tractor Co., Euclid and E. 193rd	First Monday
Columbus	C. T. Greenidge	R. E. Christin	Columbus Bolt Works	Irregular
Dayton	Milton R. Whitmore	Chester L. Gillum	The Dayton Power & Light Co.	Second Wednesday
Detroit	E. L. Morrison	R. W. Roush	Timken Detroit Axle Co., 100 Clark Ave.	Second Monday
Fort Wayne	E. J. Pavesic	R. J. McCracken	Studebaker Corp.	Fourth Tuesday
Georgia	D. D. Beach	M. F. Wiedl	Bell Aircraft Corp., Dept. 72, Marietta	First Monday
Golden Gate	V. P. Beauchamp	H. E. Krayenbuhl	Oliver United Filters, 2900 Glascock St., Oakland, Calif.	Third Monday
Hartford	DeVon W. Fryback	Ovide G. Hogaboom	27 Hart St., New Britain, Conn.	Second Tuesday
Indianapolis	Tom Harvey	R. W. Stahl	724 K. of P. Bldg.	Third Monday
Inland Empire	J. G. McGivern	George F. Mitchell	514 W. 19th Ave., Spokane, Wash.	—
Kansas City	F. A. McCoy	G. S. Young	Kansas City Power & Light Co.	Last Wednesday
Lehigh Valley	Robert D. Stout	R. L. Deily	Bethlehem Steel Co., Bethlehem, Pa.	First Friday
Los Angeles	C. E. Carlson	W. J. Parsons	Pacific Scientific Co., 1430 Grande Vista	Third Thursday
Louisville	L. W. Hennings, Jr.	Raymond B. Smith	Reynolds Metals Co., Plant No. 7	Third Tuesday
Mahoning Valley	J. Trantin, Jr.	Howard Dunkle	276 Cadillac Dr., Youngstown, Ohio	Second Tuesday
Manitoba	Chas. E. Pydee	E. M. Evans	706 Sherbrook St., Winnipeg, Manitoba	Second Thursday
Milwaukee	Walter Edens	E. G. Guenther	Wisconsin Motor Corp.	Third Tuesday
Missouri School of Mines	D. F. Walsh	Wm. J. Barnett	707 State St., Rolla, Mo.	—
Montreal	H. T. Hamon	Mrs. B. W. McGillivray	Box 371, Station 'H', Montreal, P. Q.	First Monday
Muncie	Rea Hahn	Herman Abel	Delco Remy, Anderson, Ind.	Second Wednesday
New Haven	F. E. Stockwell	H. C. Irving	Bridgeport Brass Co., Bridgeport, Conn.	Third Thursday
New Jersey	S. Skowronski	William Klaile	78 Midland Pl., Newark, N. J.	Third Monday
New York	J. B. Austin	H. C. Bostwick	40 Wall St., Room 2410	Second Monday
North Texas	C. D. Havens	Robert A. Stewart	3704 Shenandoah, Dallas, Texas	Third Wednesday
North West	LeRoy D. Wolff	Alexis Caswell	200 Builders Exchange Bldg., Minneapolis	Irregular
Northwest Penn.	Robert M. Spencer	Herbert E. Weber	Universal-Cyclops Steel Co., Titusville	—
Notre Dame	F. H. Craven	E. G. Mahin	University of Notre Dame, Ind.	Second Wednesday
Ontario	K. L. Morris	J. L. Balleny	Canada General Electric Co., Toronto, Ont.	First Friday
Oregon	W. J. Kollas	H. H. Hewitt, Jr.	Steel Tank & Pipe Co., Portland, Ore.	—
Penn State	H. B. Northrup	D. F. McFarland	Metallurgy Dept., Penn State College	Irregular
Peoria	W. Naumann	Matthew C. Aljanich	710 Haungs St.	Second Monday
Philadelphia	A. W. Grosvenor	Frederick Cooper	The Midvale Co., Nicetown, Philadelphia	Last Friday
Pittsburgh	Maxwell Gensamer	H. L. Walker	Box 6621, N. S. Station	Second Thursday
Pueblo Group	V. W. Johnson	J. F. Jones	Colorado Fuel & Iron Corp.	Third Thursday
Puget Sound	Merle B. Sell	Ralph Winship	Columbia Steel Co., 1054 4th Ave., S., Seattle, Wash.	Irregular
Rhode Island	R. F. Harvey	Carl G. Peterson	Providence Gas Co., Providence, R. I.	—
Rochester	E. M. Shaw	E. L. Spanagel	Rochester Gas & Electric Corp., 89 East Ave.	Second Monday
Rockford	Ural Gillett	H. E. Habecker	Mattison Machine Works	Fourth Wednesday
Rocky Mountain	C. C. Drake	J. F. Musgrove	Rio Grande Railroad, Denver, Colo.	Third Friday
Saginaw Valley	H. W. Schmidt	E. R. Wilson	1213 Welch Blvd., Flint, Mich.	Second Tuesday
San Diego	W. J. VanDenAkker	J. C. Scurlock	2019 Ft. Stockton Dr.	Third Friday
Schenectady	A. A. Breault	Constance B. Brodie	General Electric Co., Research Lab.	Second Tuesday
Southern Tier	J. Donald MacQueen	James S. Meyer	International Business Machines Corp., Endicott, N. Y.	Third Monday
Springfield	H. Corwin Miller	Charles S. Leonard	366 Grove St., Chicopee Falls, Mass.	Third Monday
St. Louis	W. A. Peters	S. B. Knutson	Standard Steel Spring Company	Third Friday
Syracuse	E. G. White	J. G. MacAllister	Syracuse Heat Treating Co.	First Tuesday
Texas	Carl S. Cook	W. E. Burndrett	Hughes Tool Co., Houston, Texas	Fourth Tuesday
Toledo Group	Walter Doutt	Herman Guenther	3411 Alexis Rd.	Fourth Monday
Tri-City	Fred C. Ewert	Mark A. Ashmore	Rock Island Arsenal, Rock Island, Ill.	Second Tuesday
Tulsa	Luther A. Best	Albert I. Moore	Spartan Aircraft Co., Inc.	Third Tuesday
Warren	John C. Barrett	E. W. Husemann	Copperweld Steel Co.	Second Thursday
Washington	T. L. Stivers	John A. Bennett	National Bureau of Standards	Second Monday
West Michigan	C. H. Lloyd	Dorothy M. Ridgeway	Continental Motors Corp., Muskegon	Third Monday
Wichita	G. A. Sellers	Eldon A. Means	407 W. Douglas Ave.	Second Wednesday
Worcester	Rudolph A. Johnson	George H. Campbell	Pratt and Inman	Second Wednesday
York	G. E. Shubrooks	Chas. M. Strickler	General Machine Works	Second Wednesday

Metal Powder Association

29 WEST FORTY-SIXTH STREET

NEW YORK CITY

Objects

ARTICLE II, *Section 1.* The purpose of the Association shall be to adopt standards and specifications for the various metal powders; to disseminate information among the members of the Association for the purpose of reducing the hazards of workers in the production of metal powders; to keep the users and consumers of metal powders and the public generally informed of the possibilities of and limitation upon the use of metal powders; to secure favorable rail and other transportation rates for metal powders; to secure equitable tariff legislation to assure the growth and development of the industry on a sound basis; to act as a liaison group between the producers of metal powders and technical societies, fabricators of parts made from metal powders and other organizations interested in the use and development of metal powders, and to promote the welfare of the industry.

Members:

The Aluminum Bronze Powder Company, Bedford, Ohio
Aluminum Company of America, Pittsburgh 19, Pa.
The American Metal Company, Ltd., New York, N. Y.
Apex Smelting Company, Chicago 12, Illinois
Baer Bros., New York, N. Y.
Thomas A. Edison, Inc., West Orange, New Jersey
General Aniline Works Division, New York, N. Y.
The Goldfield Consolidated Mines Co., San Francisco 4, Calif.
The Harshaw Chemical Company, Cleveland, Ohio
The O. Hommel Company, Pittsburgh, Pa.
McAleer Manufacturing Company, Rochester, Michigan
Metals Disintegrating Company, Inc., Elizabeth B, New Jersey
Metals Incorporated, San Francisco, Calif.
Metals Refining Company, Hammond, Indiana
National Magnesium Corp. of Md., Elkton, Maryland
The National Smelting Company, Cleveland, Ohio
The New Jersey Zinc Company, New York, N. Y.
Plastic Metals, Inc., Johnstown, Pa.
Pyron Corporation, Niagara Falls, N. Y.
Reynolds Metals Company, Richmond, Virginia
Unexcelled Manufacturing Company, New York, N. Y.
U. S. Magnesium Company, Pleasant Valley, N. Y.
The S. K. Wellman Company, Cleveland, Ohio

You are Invited to attend the technical discussion on Metal Powders, under the auspices of the M.P.A., on Tuesday Afternoon, October 17th, at 2:00 p. m., in the Cleveland Auditorium, during National Metal Congress

War Work Kept us
but we're not too busy
Post War Work with

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Bulletin G — Audubon Metalwove Belts of Chain Drive Type

Bulletin L — Audubon Metalwove Belts for Metal Quenching

Bulletin F — Audubon Metalwove Belts for High Temperature and Air Drawing Furnaces

Bulletin A — Audubon Metalwove Belts for Washing and Drying

AUDUBON

FACTS YOU SHOULD KNOW ABOUT CUSTOM-GRINDING ORES AND MINERALS

THE REDUCTION in size of ores and minerals by grinding is a process probably as old as man. Progress generally has been in the direction of finer particle sizes, and, curiously enough, production of finer particles is usually attended by the discovery of new properties and consequently new uses for materials. The mechanics, advantages and economics of grinding are, therefore, of substantial interest to metal men.

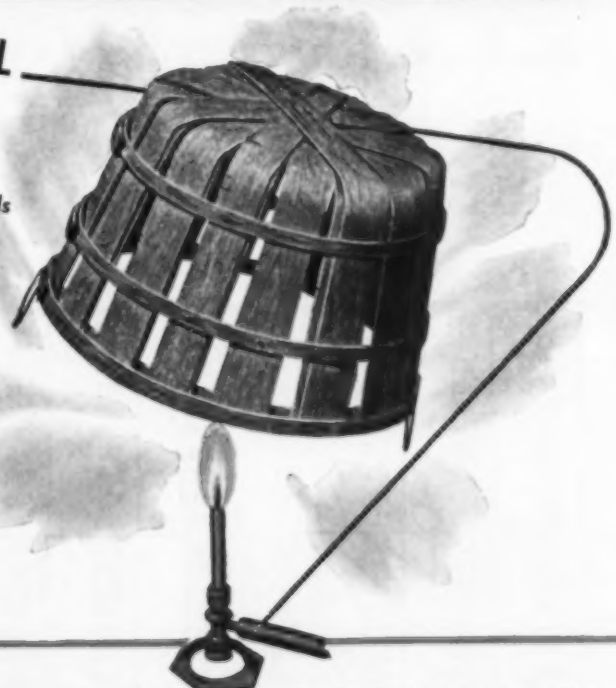
There is nothing secret or new about grinding equipment. Almost anyone is familiar with the operation of impact mills for coarse grinding, ball-race and roller mills for fine grinding, air classifiers for ultra fine grindings and rolls for producing granulation—though many improvements have been made in recent years. The same is true of corollary processes such as tabling, calcining, drying and magnetic separation. Our several plants have a wide diversity and large number of all these types of equipment for custom grinding, beneficiating or treating a great variety of ores and minerals.

More important to you, perhaps, is our more than twenty-five years of experience in processing a multiplicity of materials, years in locating sources of materials, in selecting the right types of mills or equipment to produce the product wanted at an acceptable price, years of meeting specifications exactly, and laboratory control of all production.

The Mineral Division of Foote invites you to take advantage of its own processed ores and minerals or to use its facilities for custom-grinding or treatment of ores or minerals purchased by you. A request from you for information or prices will be promptly taken care of.

THE LIGHT UNDER OUR BUSHEL

If there be a light under our "bushel" it is the purposeful glow of a Bunson burner, throwing new light on lithium, strontium, zirconium and a host of other ores and minerals packed with industrial possibilities. Through research and processing Foote brings new ideas and products to your eyes; works with you in their development. Now is the time to let us help you take advantage of Foote research and manufacture.



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WHAT'S NEW

IN MANUFACTURER'S LITERATURE

METAL WORKING • FABRICATION

Powdered metal presses. Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Chambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

Catalog 44 is a new and enlarged reference to Kennametal tools and products. Graphically indexed, this 48-page catalog covers many metal working features. Kennametal, Inc. Bulletin 541.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

Practical data sheet describes cutting and grinding compound. Diversey Corp. Bulletin 447.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Complete and valuable study of "Machining of Metals", including chip formation, is offered by National Refining Co. Bulletin 335.

Safe-T tongs and their use in materials handling are described in new booklet by Heppenstall Co. Bulletin 434.

63-page pocket booklet shows useful tables of weights and measures used in the metal industry. Mesta Machine Co. Bulletin 441.

This company has issued two new booklets showing new price lists for sintered carbides. Firth-Sterling Steel Co. Bulletin 486.

Attractive 16-page booklet describes the new "MX" grinding tools, citing many features and applications. Carborundum Co. Bulletin 518.

Struthers Wells Corportion's Tangent Bender and its ability to edge bend sheet metal in the lighter gauges is described in illustrated 8-page leaflet. Bulletin 520.

8-page general catalog outlines the hard facing alloys and overlay metals of this company, with many illustrations and typical applications. Wall-Colmonoy Corp. Bulletin 484.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

Attractive new bulletin describes the Spencer Turbine Co.'s Sump-Vac, a new portable vacuum producer which is said to clean machine sump tanks in 2 to 10 min. Bulletin 494.

Pictorial 6-page leaflet describes use of Norton Co.'s resinoid grinding wheels on snagging jobs. Bulletin 550.

Steam drop hammers up to 75,000 pounds are described in booklet offered by Erie Foundry Co. Bulletin 562.

DoAll Zephyr cutting machine and its many advantages for metals and other materials is described in new illustrated literature. Continental Machines, Inc. Bulletin 564.

Use Handy Coupon Below for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 654, 656, 658, 660, 662, 664, 666, 668, 670, 672, 674, 676, 680, 681, 688, 892, 896, 897, 898, 972, 988, 989 and 993.

Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio — October, 1944

Send me the Literature I have indicated below.

Name ..... Title .....

Company ..... Address .....

(Students—please write direct to manufacturers.)

Check or circle the numbers referring to literature described on these 24 pages.

1	59	106	147	180	246	328	367	436	465	500	527	550	571	591
2	62	107	148	182	255	329	368	437	470	501	528	551	572	592
3	65	109	149	185	258	330	369	440	471	502	529	552	573	593
4	66	114	150	186	271	331	372	441	472	504	530	553	574	594
5	70	115	152	189	281	333	380	445	473	506	531	554	575	595
7	71	116	154	190	284	335	383	446	475	507	532	555	576	596
8	72	117	155	192	288	337	385	447	477	508	533	556	577	597
10	79	118	156	193	292	338	388	448	478	509	534	557	578	598
12	82	119	158	197	296	339	390	449	481	511	535	558	579	599
21	85	123	161	199	297	343	399	450	483	512	536	560	580	600
25	86	128	162	200	305	345	404	452	484	513	537	561	581	601
26	89	132	164	203	307	347	406	453	486	515	538	562	582	602
33	93	134	167	204	314	353	407	454	487	516	539	563	583	
35	94	135	170	206	318	354	409	455	491	517	540	564	584	
40	96	137	171	208	319	359	410	457	492	518	541	565	585	
41	97	139	172	210	322	361	420	458	493	520	542	566	586	
42	98	141	173	212	323	362	424	459	494	521	543	567	587	
45	101	142	176	213	324	363	428	461	495	522	544	568	588	
51	102	143	177	215	325	364	433	462	497	525	545	569	589	
56	103	146	179	240	327	366	434	463	499	526	549	570	590	

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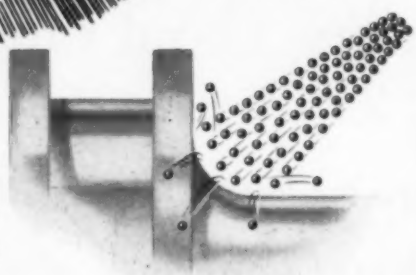

• In several fields, notably automotive and aeronautical, surface-peening (shot-blasting) is being extensively employed. Its use is spreading rapidly.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Interesting information on precision grinding is contained in this 12-page booklet "Grinding With Oil". Use of straight oils for thread grinding, gear grinding, and other precision grinding operations is discussed and well illustrated. D. A. Stuart Oil Co. Bulletin 581.

Descriptive circular presents Acme Tool Co.'s line of precision production tools of Meehanite Metal. Included are angle plates, surface plates, straight edges, lapping plates, masterangle plates, etc. Bulletin 596.

Facilities of Peerless Tool & Engineering Co. for tool building and tool design are described in literature available in Bulletin 597.

FERROUS METALS

Spindle speed calculator is handy chart to figure machining rates on bar steels. Bliss & Laughlin, Inc. Bulletin 333.

Speed Case and Speed Treat cold finished bars are described in detail in a new profusely illustrated 24-page bulletin issued by the Monarch Steel Co. Bulletin 551.

136-page, pocket-size handbook of special steels — newly revised and reprinted—describes properties, uses and best methods of handling, treatment, etc., of tool, stainless and other alloy steels. Allegheny Ludlum Steel Corp. Bulletin 575.

Properties of Frequently Used Carbon and Alloys Steels is title of big, new booklet issued by Bethlehem Steel Co. Bulletin 580.

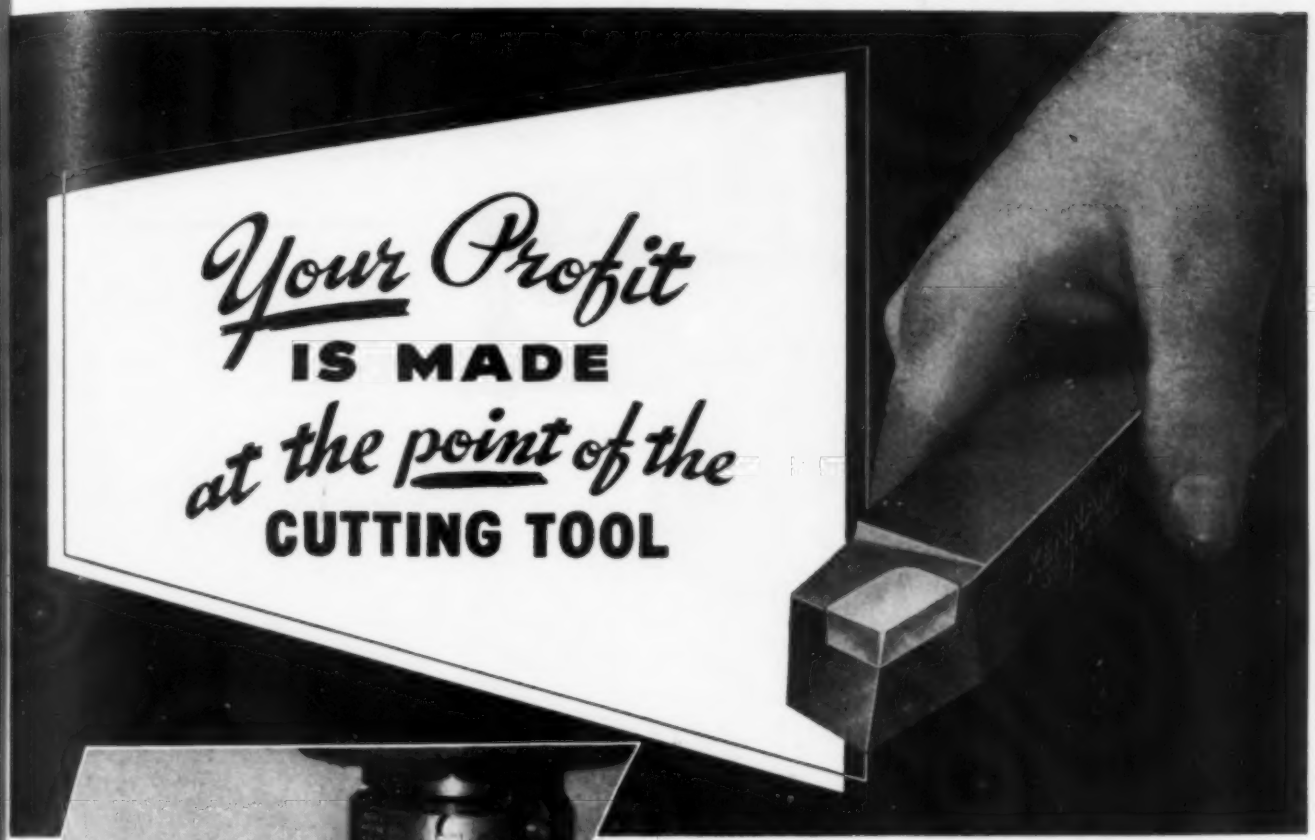
Republic Steel Corp.'s second edition of National Emergency Steels tells you all about these new steels. Bulletin 345.

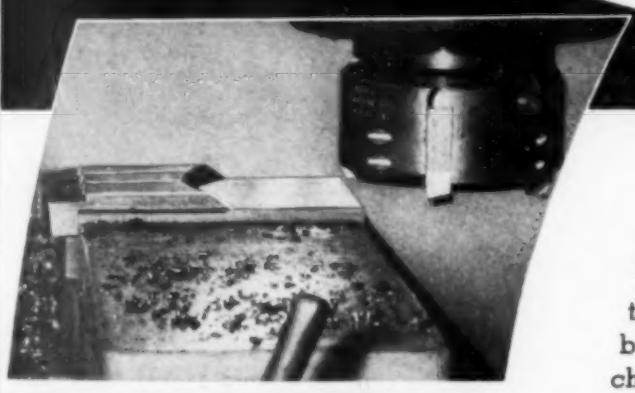
Page after page of useful technical data and reference tables on tool steels. Latrobe Electric Steel Co. Bulletin 367.

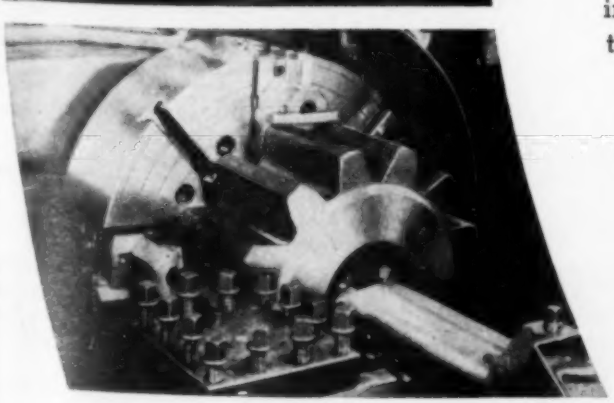
New 46-page booklet, "Wear, A Discussion of the Mechanism of Wear Phenomena and Influencing Factors", is said to be the first book in English on the subject of wear. Nitralloy Corp. Bulletin 539.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 652, 656, 658, 660, 662, 664, 666, 668, 670, 672, 674, 676, 680, 681, 688, 892, 896, 897, 898, 972, 988, 989 and 993.

Your Profit IS MADE *at the point of the* CUTTING TOOL







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Thus, Kennametal—in common with other inventions that have been brought forth under the American system of free enterprise—returns profit, not just to its inventor, nor only to the industries in which it functions, but . . . chiefly to all our people.

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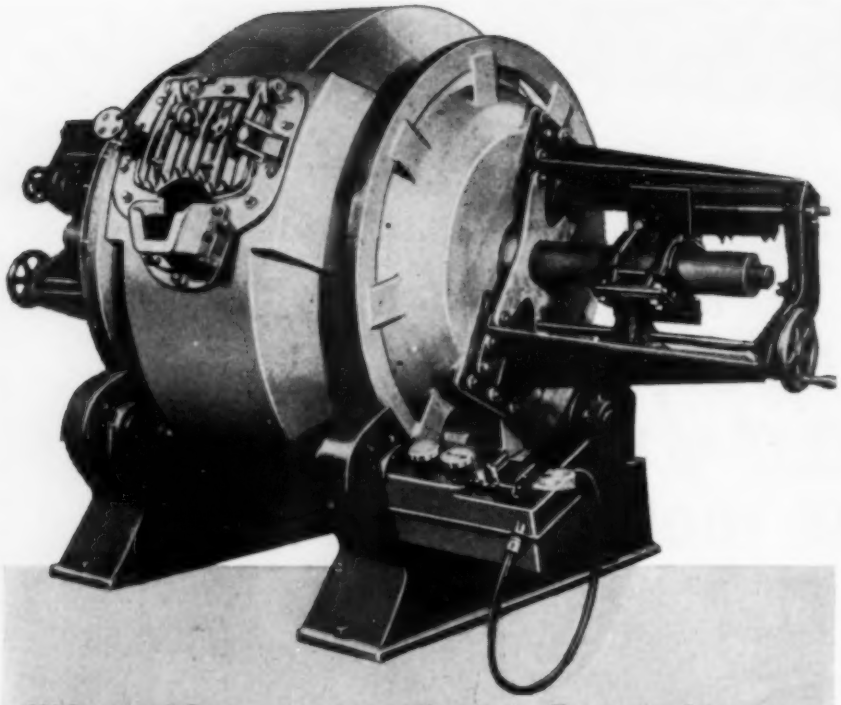

What they say about Detroit Rocking Electric Furnaces

Workmen who operate them, swear by Detroit Rocking Electric Furnaces. And for good reason. There are no products of combustion; and since melting takes place in a closed chamber, dirt and fumes are reduced to a minimum. Easy to operate, each heat is poured with the least amount of hard work.

Metallurgists are well sold on Detroit Furnaces. Because of their automatic stiring action under non oxidizing conditions and their precise control of time, temperature and composition, these efficient units assure superior metallurgical results.

Managers of foundries who know them, fully appreciate the advantages of Detroit Rocking Electric Furnaces. They insure faster melting, lower metal losses, and less machine-shop scrap. Detroit Furnaces melt more pounds per man hour. They give a higher percentage of perfect castings of uniform quality. They melt as many as 8 ferrous or 16 non ferrous heats in one eight-hour day.

From every view point, a Detroit Rocking Electric Furnace is the outstanding foundry melting unit.

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KUHLMAN ELECTRIC COMPANY • BAY CITY, MICHIGAN

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin 25.

Molybdenum wrought steels. Molybdenum Corp. of America. Bulletin 26.

Chemical analyses, shapes and sizes of Joslyn stainless steel products. Joslyn Mfg. and Supply Co. Bulletin 297.

Enameling iron sheets. Inland Steel Co. Bulletin 33.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin 35.

Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. Bulletin 40.

Attractive new catalog describes the line of steel offered by Peninsular Steel Co. Bulletin 337.

New Catalog C makes it easy to get International Nickel Co. literature, as it presents brief description and index to a wide variety of booklets. Bulletin 305.

"Graphitic Booklet" gives complete information on new, free-machining, long-wearing steel. Steel & Tube Div., Timken Roller Bearing Co. Bulletin 307.

HWD hot work die steel and Sterling stainless steels are described in four new leaflets by Firth-Sterling Steel Co. Bulletin 323.

New booklet gives full information on N-A-X high tensile and N-A-X 9100 Series of alloy steels. Great Lakes Steel Corp. Bulletin 328.

Fitzsimons Co. issues interesting leaflet on speed case and speed treat steels. Bulletin 452.

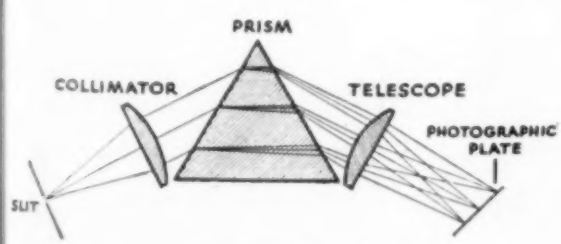
84-page tool and die steel handbook just issued by Ziv Steel & Wire Co. is a helpful guide to selection, treatment and use of these important steels. Bulletin 440.

Kinite alloy tool steel bar stock. H. Boker & Co., Inc. Bulletin 258.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 652, 654, 658, 660, 662, 664, 666, 668, 670, 672, 674, 676, 680, 681, 688, 892, 896, 897, 898, 972, 988, 989 and 993.

A spectrograph is basically a picture of a spark. Through this medium it has been possible to gain a knowledge of the composition of materials which enables us to determine their proper application and use.

All elements, when "excited" by heat or electrical discharge, emit radiations of known wave lengths. In spectrography, this light enters the slit of the spectrograph, passes through the optical system, is dispersed into its component parts (the spectrum) and recorded on a photographic plate, providing a permanent record for study. The radiation emitted by each element is made up of certain definite wave lengths which are always the same regardless of what other elements are present in the substance under investigation, and since these wave lengths are accurately known it is possible to identify each line in the spectrum from its wave length and thus gain a complete knowledge of the composition of the metal. The density of the spectral line bears a direct relation to the amount of the element present, therefore the spectrograph also provides a basis for quantitative analyses.



Simple spectrograph

The advantage of spectrographic analysis over wet chemical analytical methods is that in the former, *all* elements in the sample including those of a deleterious character are indicated, while in the latter only those elements which are *deliberately looked for* are detected.

The Bunker Hill electrolytic zinc plant has one of the most modern and complete spectrographic laboratories in the country. Utilization of such modern methods of analysis and control from ore to metal is in a large measure responsible for the continued high purity of Bunker Hill zinc—the first 99.99+% metal to be produced in commercial quantities and the forerunner of today's Special High Grade zincs.

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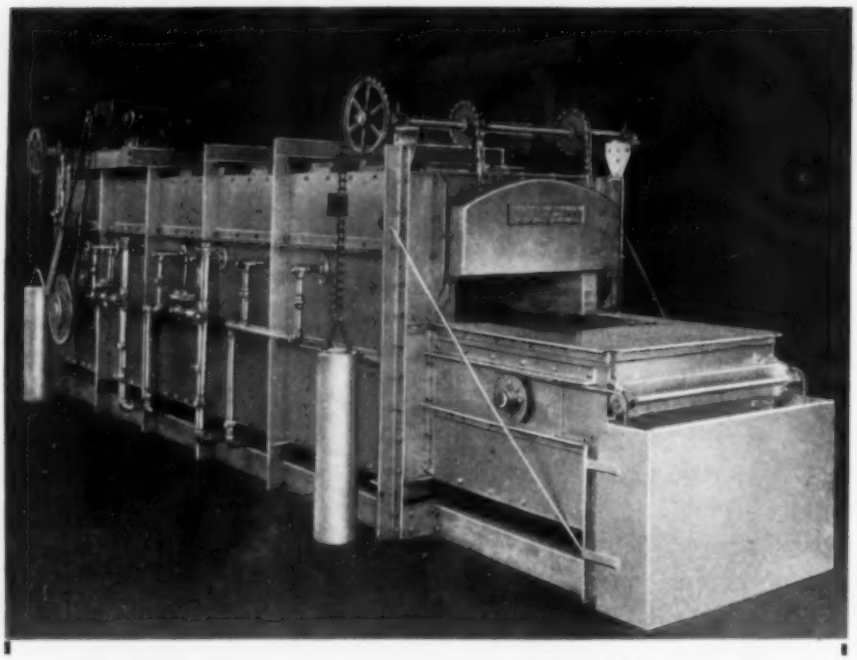
BUNKER HILL 99.99+% ZINC

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

SKF Steels, Inc., has issued a stock list of high carbon-high chrome seamless steel tubing and round bars, available for immediate delivery. Bulletin 566.

Latest data chart, Section D, No. 1, shows government "specs" for alloy steels and corresponding commercial designations. Peter A. Frasse & Co., Inc. Bulletin 533.



DIRECT FIRED CONTINUOUS HEAT TREATING FURNACES

Above is shown our continuous type, hardening furnace for temperatures up to 1700 degrees F. This furnace is designed to reduce scale and for many products, it is not necessary to resort to a fully controlled atmosphere furnace. A hot discharge end unit with conveyor belt returning inside the furnace, together with enclosed discharge chute to the quench tank prevents air infiltration into the furnace. The vents are located below the hearth level and carry off any infiltration from the charge opening before it reaches hearth level. These furnaces are lined with insulating refractory brick backed by insulating brick and are fired from the sides by heat resisting alloy tipped, tunnel type, gas burners. The conveyor belt may be cast, heat resisting alloy for heavy loads, or our own plate or open link type alloy belt made of 16 gage stampings for lighter loads.

This furnace is equipped with a water cooled discharge chute with oil curtain which prevents the oil from splashing into the furnace and igniting. The chute discharges the work directly onto the conveyor in the quench tank.

These units are available in sizes having capacities from 300 lbs. to 3000 lbs. per hour and are adaptable for a wide variety of parts such as springs, screws, nuts, bolts, automotive parts, etc.

We have built furnaces for every heat treating requirement for many years. May we help you?

INDUSTRIAL HEATING EQUIPMENT COMPANY

3570 Fremont Place • Detroit 7, Michigan

Facts on Beryllium Copper, incl ing composition, forms availab applications and extensive additio information are presented in t new 16-page booklet by the Riv side Metal Co. Bulletin 511.

32-page booklet which pictorial and textually amounts to a scienti treatise on two carbon steels — Spe Case and Speed Treat — has been i sued by W. J. Holliday & Co. Bul tin 450.

Molybdenum-Tungsten high spe steels marketed under the gener trade name Mo-Max are discuss comprehensively in 52-page book b J. V. Emmons, metallurgist for t Cleveland Twist Drill Co. Bulle 497.

Carpenter Steel Co. offers a co venient four-color chart useful i identifying various types of stainle steels which may have become mix in stock. Bulletin 507.

Important practical heat treati information about stainless ste has just been issued by Rustless Ir and Steel Corp. Bulletin 563.

100-page ring-binder catalogs D win & Milner, Inc. tool steels, d scribing selection and applicatio Bulletin 561.

New 38-page handbook for d signers of stainless steel equipme gives valuable information for acc rately proportioning stronger light parts. It is said to be the first tim such detailed values for commerci stainless, both above and below t yield point have been compile American Rolling Mill Co. Bulle 553.

NON-FERROUS METALS

80-page pipe and tube bendi handbook has been issued by Copp & Brass Research Assn. Bulletin 3

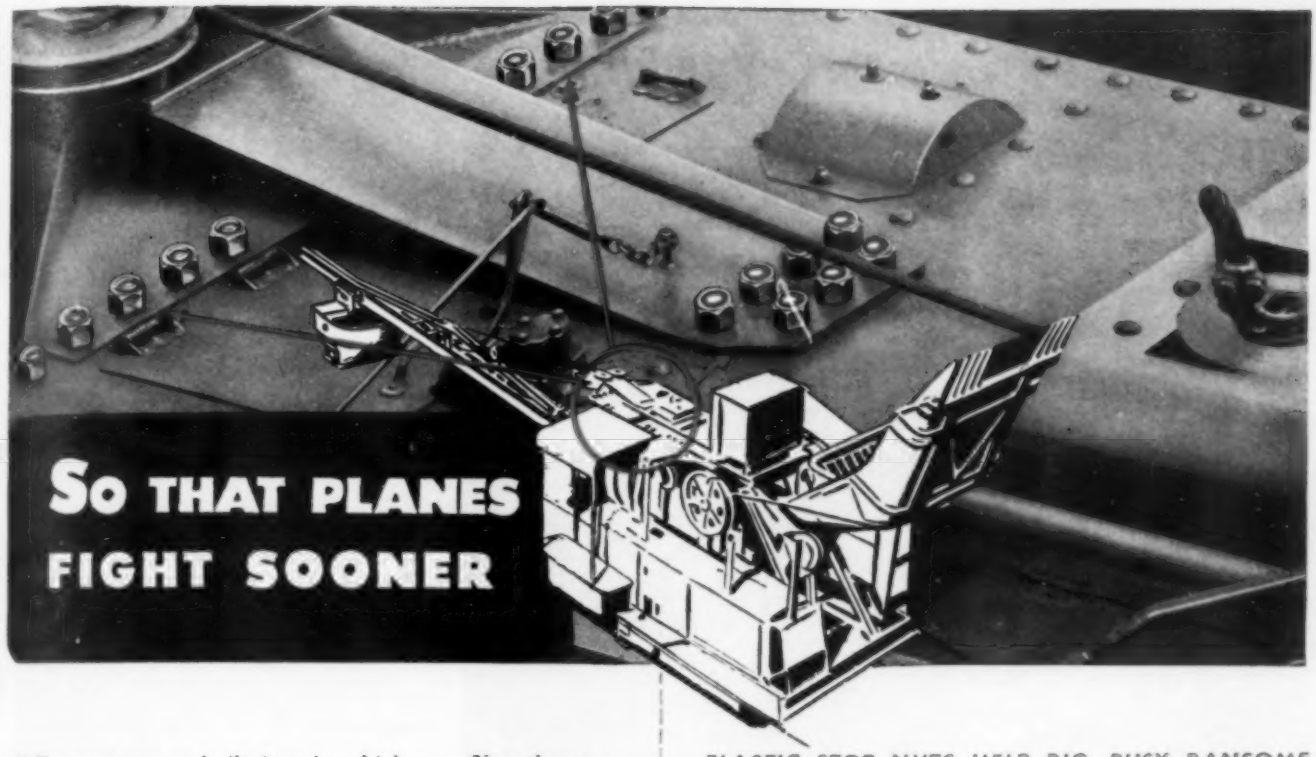
6th edition of Revere Weights a Data Handbook. Revere Copper a Brass, Inc. Bulletin 296.

This "Aluminum Imagineeri Notebook" presents 12 import economic advantages of alumin and illustrates numerous examp of things which have been ima neered into aluminum actualit Aluminum Co. of America. Bulle 472.

Copper Alloys. American Brass C Bulletin 45.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.

Other Manufacturers' Literature Lis on Pages 652, 654, 656, 660, 662, 664, 6 668, 670, 672, 674, 676, 680, 681, 688, 8 896, 897, 898, 972, 988, 989 and 993.



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● Ransome pavers built American highways. Now they are rushing airports along our battle fronts.

Every hour of construction time they can save gives that much advantage to our fighting airmen.

Paving is a shattering job. And it used to be accepted that frequent take-ups and tightening were part of paver maintenance.

But no more! Not since Ransome began using Elastic Stop Nuts—the nuts that stay put.

Now the paver keeps on the go longer, and our planes fight sooner.

The reason Elastic Stop Nuts hold tight in spite of wracking vibration lies in the elastic collar in their tops. This snuggles close around the bolt threads, grips them and prevents the nut from turning and loosening.

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ELASTIC STOP NUTS HELP BIG, BUSY RANSOME PAVERS DO MANY VITAL WAR JOBS

"Concrete road pavers are subjected to tough, grueling work, especially on twenty-four-hours-a-day service, for which many Ransome Pavers have been called upon in the construction of airport runways since the war started. All told, there are about 1,200 Elastic Stop Nuts used on every Ransome Paver we build. By substituting Elastic Stop Nuts for the ordinary kind, we are helping the Ransome Paver owner minimize his maintenance job because the nuts are self-locking and vibrationproof. No time out for tightening — no extra hours of labor to take up slack. Elastic Stop Nuts also simplify our shop assembly job. They are a further contribution to the improvement of our paver, which is our constant goal."

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Chief Engineer

RANSOME MACHINERY CO., DUNELLEN, N. J.
Subsidiary of Worthington Pump and Machinery Co.

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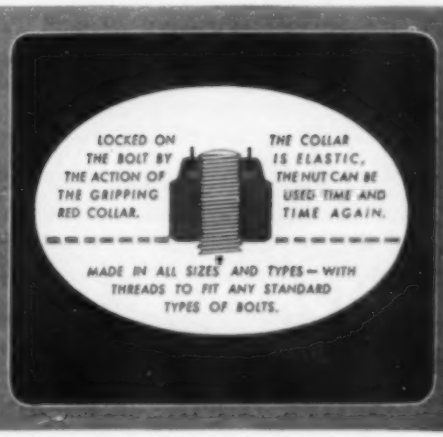
OF AMERICA

ELASTIC STOP NUTS

Lock fast to make things last

UNION, NEW JERSEY AND
LINCOLN, NEBRASKA


LOCKED ON THE BOLT BY THE ACTION OF THE GRIPPING RED COLLAR.
THE COLLAR IS ELASTIC, THE NUT CAN BE USED TIME AND TIME AGAIN.
MADE IN ALL SIZES AND TYPES — WITH THREADS TO FIT ANY STANDARD TYPES OF BOLTS.

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A LOW CARBON OPEN HEARTH PRODUCT

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin 41.

Die casting equipment. Lester-Phoenix, Inc. Bulletin 42.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

Two new Ampco Metal data sheets discuss forging Ampco to improve physical characteristics and use of Ampco for non-scratching feed fingers. Bulletin 314.

"Designing with Magnesium" is title of new book offered by American Magnesium Corp. Bulletin 433.

Printed information on Lithium of interest to nonferrous and physical metallurgists is available from Lithaloys Corp. Bulletin 532.

Two new bulletins present many interesting facts on aluminum tubing and aluminum wire, rod and bar. Reynolds Metals Co. Bulletin 540.

Red-X Aluminum Alloys, produced by the largest single producer of Commercial Aluminum and Magnesium Alloys, the National Smelting Co. are described, applications studied, in this 16-page file folder. Bulletin 499.

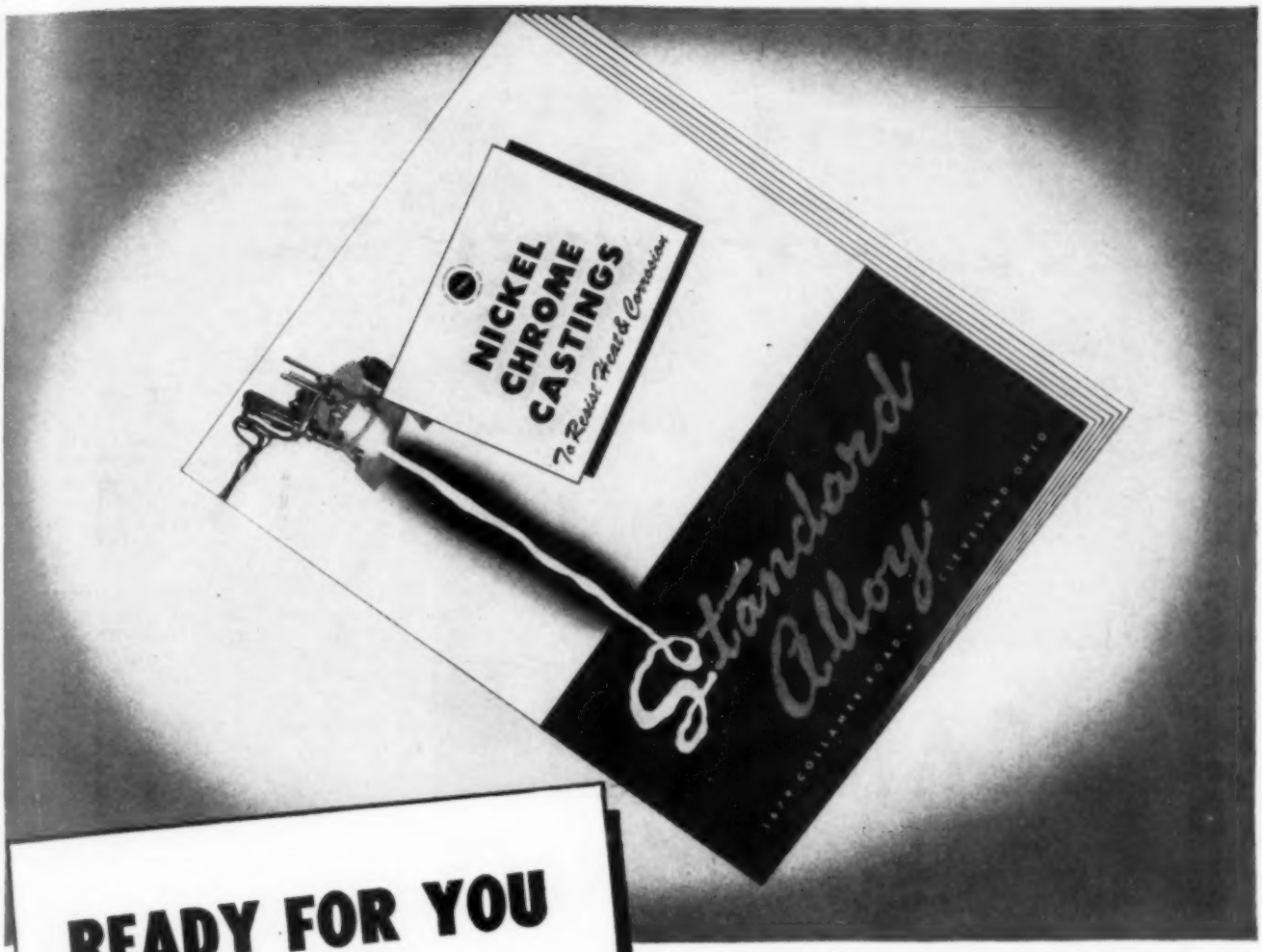
Dowmetal data book. Dow Chemical Co. Bulletin 51.

"Some Considerations in Making Test Bars" is the title of an interesting booklet by Federated Metals Div. American Smelting and Refining Co. Bulletin 529.

32-page booklet, "Revere Magnesium Alloys and the Light Metals Era", is now coming off the press with basic facts about magnesium, plus detailed technical data on physical, mechanical and working characteristics of the Revere Alloys. Revere Copper and Brass, Inc. Bulletin 579.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 652, 654, 656, 658, 662, 664, 666, 668, 670, 672, 674, 676, 680, 681, 688, 892, 896, 897, 898, 972, 988, 989 and 993.



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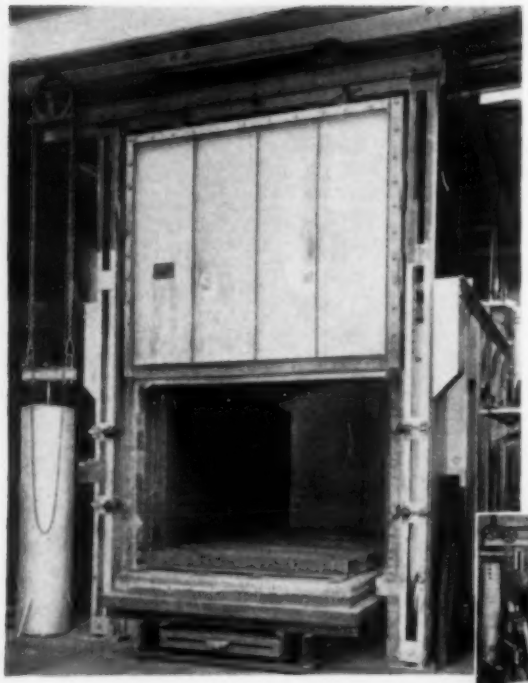

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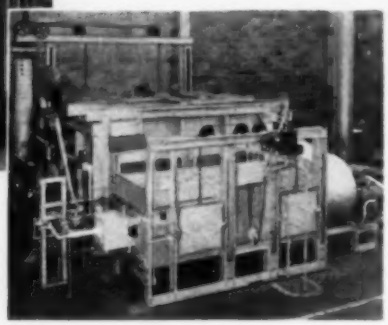

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For Stress Relief of Fabricated Parts

The VULCAN Furnace illustrated above is used for stress relief of fabricated steel parts ranging in section from ½" to 1½", at maximum temperature of 1250°F. The unit is gas fired, with complete automatic program control. Electrically controlled damper doors provided differential control over rates of heating, soaking and cooling. Double range burners are furnished with pilot- and flame-failure safety device.

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VULCAN designs and installs furnaces for all heating and heat treating operations. Consultation with our engineers will incur no obligation.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

WELDING

New method for increasing speed of welding mild steel called "Fleet-Welding" is described in new 48-page booklet issued by the Lincoln Electric Co. Bulletin 571.

This new chart gives weld metal chemical composition, heat treatment specifications and identifying grade information on Arcos Corp.'s stainless and alloys electrodes. Bulletin 572.

Bulletin GEA-4220, well-illustrated, describes features of new current regulating compensator for resistance welding. General Electric Co. Bulletin 576.

"Things To Know About Welding Stainless Steel" is title of new booklet that answers many welding questions. The McKay Co. Bulletin 544.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin 59.

40-page catalog reviews the progress and many applications of low temperature welding. Eutectic Welding Alloys Co. Bulletin 471.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin 62.

Welding and brazing of aluminum, a new data book issued by Aluminum Co. of America. Bulletin 66.

Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin 65.

Nu-Braze No. 4, an improved silver brazing alloy. Sherman & Co. Bulletin 288.

Two new hard-facing alloys furnished as welding rods for application by Oxy-Acetylene process are described by the Stoody Co. in Bulletin 325.

Comparable arc welding electrodes for stainless are shown in chart issued by Alloy Rods Co. Bulletin 353.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 652, 654, 656, 658, 660, 664, 666, 668, 670, 672, 674, 676, 680, 681, 688, 892, 896, 897, 898, 972, 988, 989 and 993.

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Shovel Steels
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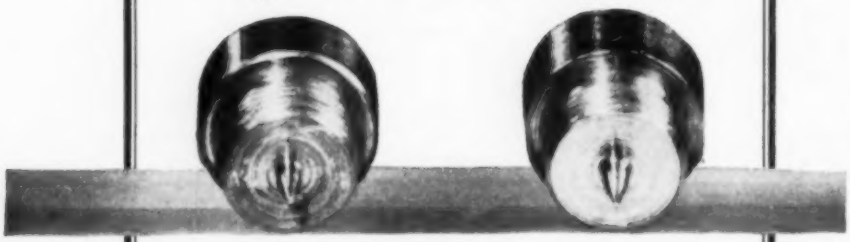
TEM-CROSS Steel
IngAclad (Stainless-Clad Steel)
Stainless Steels and Saw Steels, including "18-4-1" and Molybdenum and D-B-L Hack Saw Steels

before and after



How the right cutting fluid pays

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The stainless steel parts illustrated above are a good example. It is obvious from these unretouched illustrations that the piece on the right has the better finish on both face and thread. This improvement over the left hand piece was due solely to a change in cutting oil to the ***right*** oil for the job. And this ***right*** oil proved to cost 14c per gal. less, on the machine. In this case a simple blend of Stuart's Thred Kut 99 was the answer—but it might have been any other of several Stuart Products.

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the above parts and hundreds of others will be on display at the Stuart Oil exhibit—drop in.

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WHAT'S NEW

IN MANUFACTURERS' LITERATU

New Phos-Copper booklet explai ways to braze, design and applic tions. Westinghouse. Bulletin 4

32-page booklet presents numer experience reports from large us of arc welding. General Electric Bulletin 513.

Air Reduction Sales Co. offe 20-page revised price list, "Gas a Electric Welding Supplies and Acce sories". Bulletin 512.

Bulletin No. 14, "How To Repa Broken Cutting Tools With Eas Flo", is filled with practical, instruc tional copy, profusely illustrate Handy & Harman. Bulletin 506.

Pocket-sized, slide-type guid showing proper tip sizes, gas pre sures, and other data required f machine gas-cutting steel is offere by Air Reduction. Bulletin 527.

16-page booklet illustrates th design and construction features certain types of Victor single an two-stage reduction regulators em ployed in the welding industry Victor Equipment Co. Bulletin 55

End-welding with Nelson studs i less than ½ second is described catalog and price list issued by Nel son Specialty Welding Equipmen Corp. Bulletin 565.

TESTING & INSPECTION

"Faxfilm", a new, economica quick method of inspecting surfac finishes through enlarged Thre Dimensional Replica, is describe and illustrated in an interestin 4-page leaflet by Rex D. McDil Bulletin 602.

High temperature electric furnace for sintering both ferrous and non ferrous powders are described i this bulletin by Harper Electric Fur nace Corp. Bulletin 587.

New Burrell Shaker for genera laboratory use is described in new catalog issued by Burrell Technica Supply Co. Bulletin 543.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 652, 654, 656, 658, 660, 662, 664, 668, 670, 672, 674, 676, 680, 681, 688, 892, 896, 897, 898, 972, 988, 989 and 993.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin 86.

The Bristol-Rockwell dilatometer and its use is described in this leaflet by The Bristol Co. Bulletin 465.

Metallurgical polishing equipment offered by Precision Scientific Corp. is described in illustrated booklet. Bulletin 359.

Various methods and specific applications of the measurement of case depth are described in illustrated pamphlet offered by Allen B. DuMont Laboratories, Inc. Bulletin 339.

Bibliography of more than 700 papers dealing with the polarographic method of metal analysis and a booklet discussing this equipment is offered by E. H. Sargent & Co. Bulletin 338.

SR-4 strain gage and illustrations of its many uses. Baldwin Southwark. Bulletin 70.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin 72.

New book contains wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin 71.

Latest technical literature on x-ray and radium protection, together with lead products catalog, has been issued by Bar-Ray Products, Inc. Bulletin 463.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin 79.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin 85.

Optical Aids. Bausch & Lomb Optical Co. Bulletin 94.

Metallographic polishing powder. Conrad Wolff. Bulletin 96.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.

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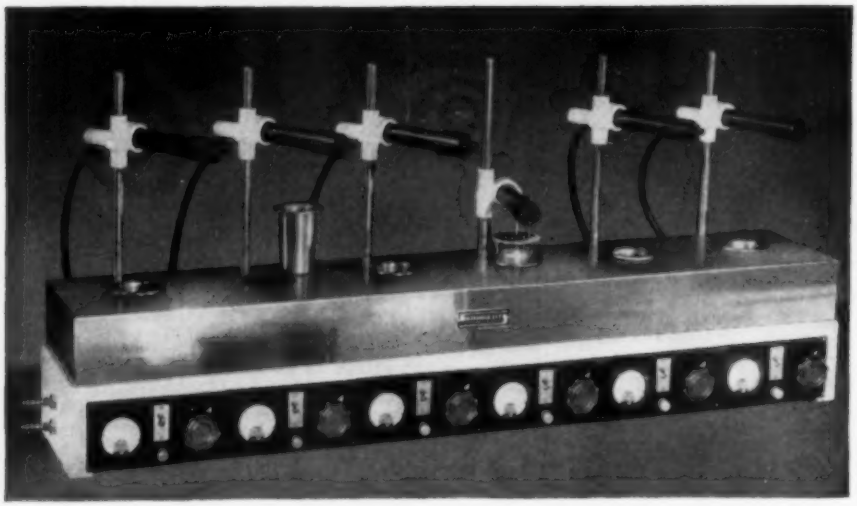

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It applies high current densities up to a limit of 10 amperes to greatly increase rates of deposition and produce bright, smooth, closely grained deposits that firmly adhere to electrodes. Use of high speed methods possible with the Sargent electrolytic analyzer reduces the time formerly required for making analyses by as much as 60%.

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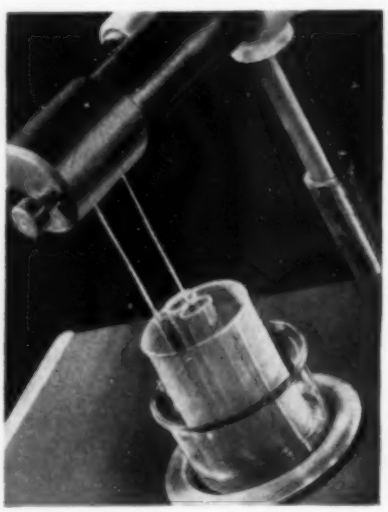

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SCIENTIFIC LABORATORY SUPPLIES

WHAT'S NEW

IN MANUFACTURERS' LITERATU

New Norelco electronic Searchl Modal 150 is described and sev features illustrated in this 4-p leaflet. North American Philips Inc. Bulletin 517.

"Radiography of Materials" is t of new 96-page book on indust radiography. Eastman Kodak Bulletin 331.

High intensity industrial illu nator is illustrated and described new leaflet by Kelley-Koett Mfg. Bulletin 406.

30th Anniversary Catalog sho the special metallurgical equipm offered by Claud S. Gordon Co. B letin 410.

Details and various applications the portable tensile tester are sho in 8-page leaflet by W. C. Dillon Co., Inc. Bulletin 491.

Advantages and speed of testi with the Magnetic Analysis Corp Comparator are described and pi tured in brochure just released. B letin 492.

8-page illustrated leaflet descri line of industrial instruments fered by the Brush Development Bulletin 428.

Hardness testing equipment. W son Mechanical Instrument Co., I Bulletin 98.

New Carbon and Sulphur Det minator is described in this n 8-page leaflet. Harry W. Dietert Bulletin 501.

Many tips and suggestions industrial laboratories are presente in 24-page March issue of "Curv and References" by Wilkens-Ani son Co. Bulletin 502.

4-page folder on the inspecti and control of surface finish offered by George Scherr Co. B letin 508.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.
Other Manufacturers' Literature Listi on Pages 652, 654, 656, 658, 660, 662, 6 666, 670, 672, 674, 676, 680, 681, 688, 8 896, 897, 898, 972, 988, 989 and 990.

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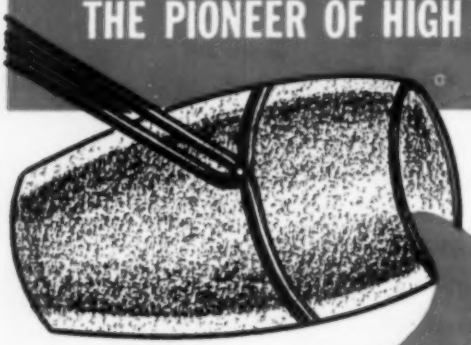
WHAT'S NEW

IN MANUFACTURERS' LITERATURE

6-page leaflet describes the constant temperature equipment offered by American Instrument Co. Bulletin 493.

New 50 KV industrial x-ray unit, its features and applications, are presented in this 8-page leaflet. Picker X-Ray Corp. Bulletin 525.

THE PIONEER OF HIGH SPEED TOOL STEELS



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Metallurgical Equipment. Ad... I. Buehler. Bulletin 97.

Attractive, illustrated booklet ... scribes Clark Instrument's preci... hardness tester. Bulletin 318.

TEMPERATURE CONTRO...

A portable instrument for mea... ing temperatures of glowing ob... is described in 16-page catalog ... tical Pyrometer" recently repri... with minor changes by the Lee... Northrup Co. Bulletin 569.

4-page bulletin describes ... Throttltrol as a simplified valve p... tioning device to be used in com... tion with any control instru... having a high and low contact ... a neutral position. Operation ... features are detailed. Wheelco ... struments Co. Bulletin 582.

Potentiometer temperature ind... tors. Foxboro Co. Bulletin 82.

Micro-Optical Pyrometers. Pyr... eter Instrument Co. Bulletin 88.

Pyrometer control of high sp... salt baths is described in new bu... let by Brown Instrument Co. Bu... tin 324.

Industrial thermocouples. Ari... S. Richards Co. Bulletin 93.

Operating principle and ty... available of the synchronous-mo... driven cam program timer are c... ered in this new 4-page fold... Automatic Temperature Control ... Inc. Bulletin 487.

New bulletin with 12 pages of ... formation on application, operat... and design of Bristol Co.'s radiat... pyrometers has just been releas... Bulletin 592.

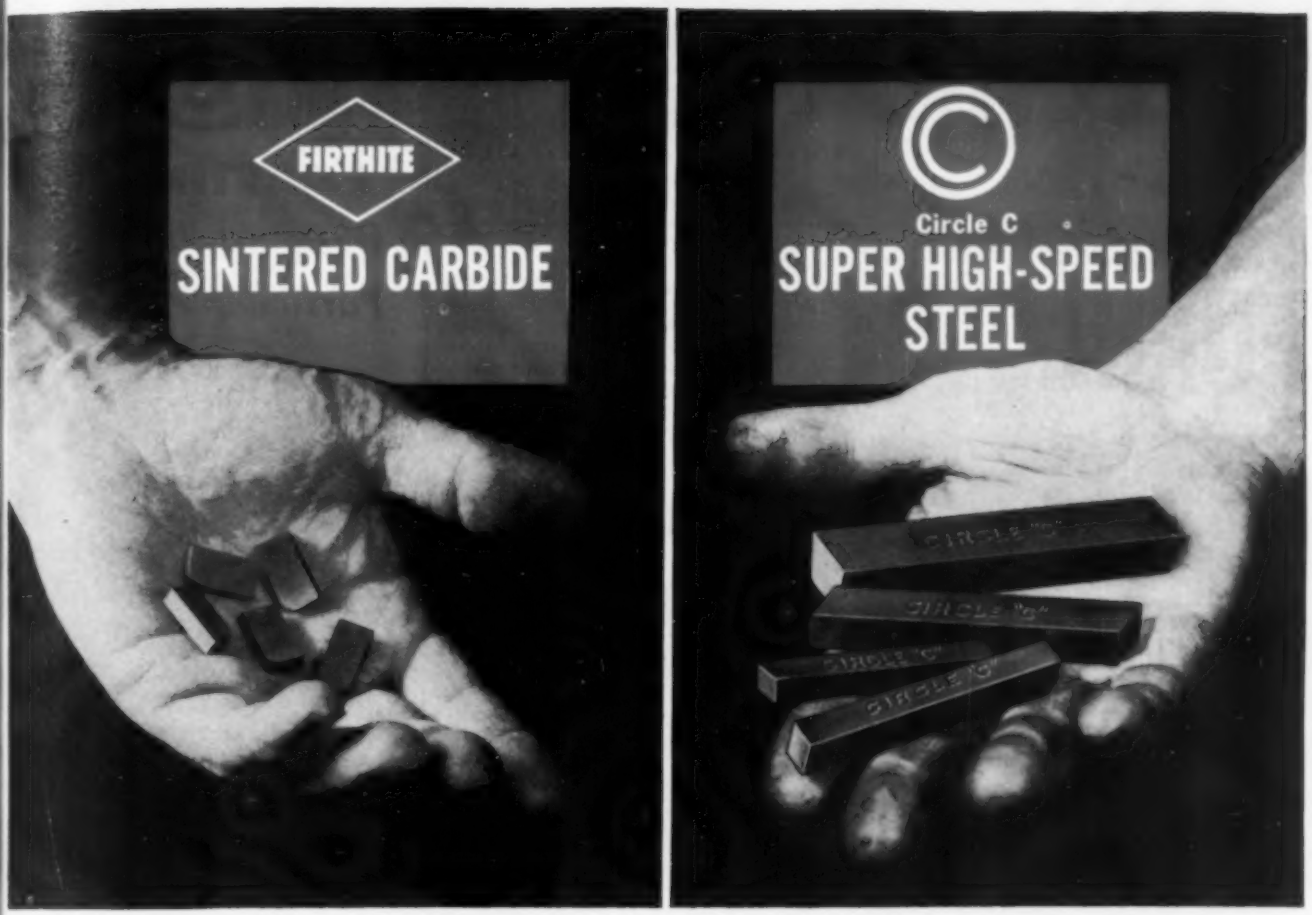
Alnor Pyrocon, the contact pyr... eter for surface temperatures, ... described in this 6-page leaflet ... Illinois Testing Laboratories, ... Bulletin 558.

HEATING • HEAT TREA... MENT

New bulletin MP115 describes ... F. Holden Co.'s flow heat treatin... for bright hardening, bright temp... ing and hot quenching. Bulletin ...

Use Handy Coupon on Page 652 for Ordering Helpful Literature.

Other Manufacturers' Literature Lis... on Pages 652, 654, 656, 658, 660, 662, ... 666, 668, 672, 674, 676, 680, 681, 688, ... 896, 897, 898, 972, 988, 989 and 993.



THERE ARE PLACES FOR BOTH . . .

Firth-Sterling, long specialists in making steels for shop tooling, early recognized the possibilities of carbides as a means of extending the improvement in shop practice brought about by the super high-speed steel—CIRCLE C. **But, there is a place for both . . .**

Where the highest speeds are obtainable or materials are hardest, FIRTHITE is the "last word" in a cutting material. It is used at speeds up to ten times those possible with high-speed steels. Where speeds above average are permissible or materials are "on the hard side," CIRCLE C will cut *at least* 25% faster than ordinary grades of high-speed steel. Send for descriptive literature on these remarkable materials.

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turns two to ten times more pieces of heat-treated alloy steel between grinds than other high-speed steels.

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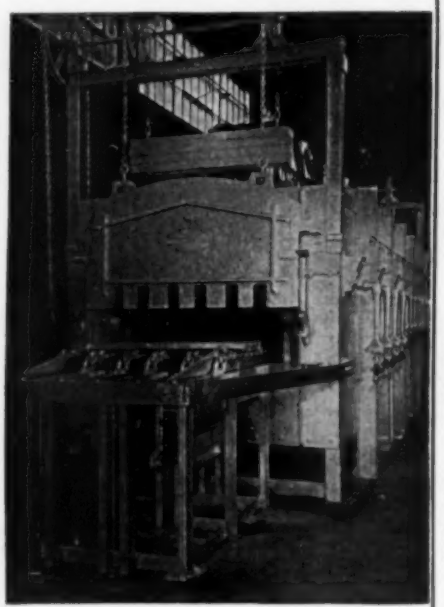

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

24-page Catalog Section M-8802 describes Karbate corrosion resistant heat exchange equipment. Booklet sets forth several charts and tables covering heat conductivity and physical and chemical properties of carbon, graphite and Karbate materials. National Carbon Co., Inc. Bulletin 570.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin 106.

Radio frequency generators for cutting heating time are described by Westinghouse Electric & Mfg. Co. in Bulletin B-3261-A and Descriptive Data 85-800. Bulletin 577.

40-page booklet contains complete information on cold treating, including new procedures, applications, performance data stories, etc. Deepfreeze Div., Motor Products Corp. Bulletin 578.

Design features of Surface Combustion standard rated convection furnaces are described and illustrated in this 8-page leaflet. Bulletin 588.

Junior Quencher for controlled quenching where small pieces are heat treated is described in 4-page leaflet by Bell & Gossett Co. Bulletin 591.

New 12-page fully-illustrated bulletin on heat treating ovens has just been published by Young Brothers Co. Illustrated are typical examples of ovens for heat treating aluminum and magnesium parts, for aging, stabilizing and hydrogen relief of plated parts, for pre-heating, for temper drawing and for stress relief. Bulletin 599.

Chapmanizing imparts costly alloy-hardness to steels faster than any other process, according to literature available from the Chapman Valve Mfg. Co. Bulletin 600.

Open fire, case-hardening compound for surface hardening all kinds of iron and steel is described in literature by the Kasenit Co. Bulletin 601. . . .

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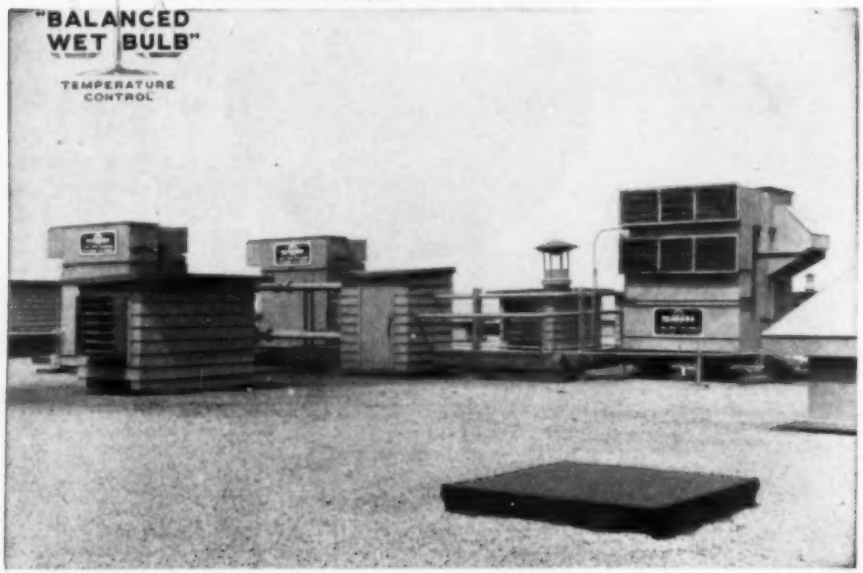

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Attractive 4-page leaflet describes uses, construction features and design of electric car bottom furnaces. Hevi Duty Electric Co. Bulletin 532.

McKee "Wallitite Proportioning" and "Entrainment" gas burners are described in new bulletin by Eclipse Fuel Engineering Co. Bulletin 530.

Convection tempering furnaces with temperatures up to 1300 deg. F. are described in this new Hevi Duty Electric Co. Bulletin 542.

Internally heated salt bath furnaces and pots. Upon Electric Furnace Div. Bulletin 102.

32-page booklet describes 16 interesting industrial uses of high frequency electrical induction. Ohio Crankshaft Co. Bulletin 459.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin 107.

"Isothermal Quench Baths Applied to Commercial Practice" is the title of this 12-page paper, a practical and useful discussion of S curves in heat treatment. Ajax Electric Co. Inc. Bulletin 461.

Quenching oil coolers in heat treating practices are described in this leaflet by the Sims Co. Bulletin 402.

Induction heating. Induction Heating Corp. Bulletin 103.

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin 101.

Furnaces for heat treatment of aluminum, magnesium and their alloys. Lindberg Engineering Co. Bulletin 271.

Gas, oil, and electric heat treating and carburizing furnaces. Holcroft & Co. Bulletin 114.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin 134.

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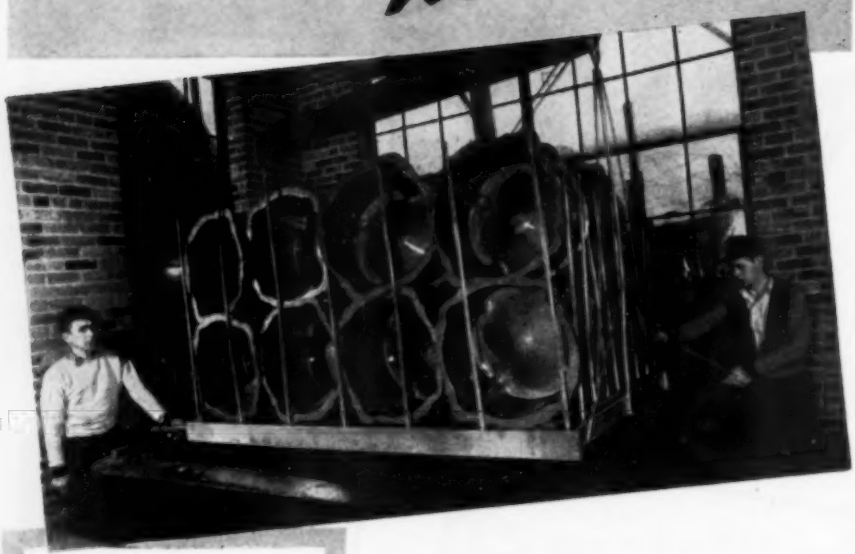

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin 115.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin 116.

Full muffle and other heat treating furnaces described in catalog by Charles A. Hones, Inc. Bulletin 117.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin 119.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin 118.

Molten Salt Baths. E. I. duPont deNemours & Co., Inc., Electrochemicals Department. Bulletin 123.

Handling cylinder anhydrous ammonia for metal treaters. Armour Ammonia Works. Bulletin 128.

Air-Oil Ratiotrol for proportioning flow of fuel oil and air to oil burners. North American Mfg. Co. Bulletin 135.

Two new bulletins on vertical carburizers and on carbonia finish. American Gas Furnace Co. Bulletin 139.

Controlled atmosphere furnace. Delaware Tool Steel Corp. Bulletin 141.

Dual-Action quenching oil. Gulf Oil Co. Bulletin 132.

Heat treating, brazing and melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin 147.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin 143.

Vertical Furnace. Sentry Co. Bulletin 148.

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"Beaten Paths are for Beaten Men," *says Eric Johnston*

Look, Mr. Johnston, how production and construction men are stepping out in front in welding speed and economy with Lincoln "Fleet-Welding":

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Typical actual step-ups in welding speed reported by two fabricators:

350% FASTER BUTT WELDING

"Arc Force" of "Fleet-Welding" makes possible square edge butt joints and two-pass welding of plate as heavy as ⅜"... 9" of joint per min., compared to 2" per min. with conventional technique . . . a Pittsburgh Tank Builder.

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"Fleet-Welding" digs into the corner . . . in the case of ½" plate, cuts the amount of deposited metal by 50% and boosts welding speed from 5" per minute to 12" per minute. Cuts cost 59% . . . a Cleveland Structural Fabricator.

Full details and "Fleet-Welding" procedures in Bul. 440. Free on request. Consult the Lincoln Welding Engineer near you.

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R-S Furnaces of Distinction

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Furnaces. Tate-Jones Co. Bulletin 142.

Conveyor Furnaces. Electric Furnace Co. Bulletin 149.

High and low temperature direct fired furnaces. R. S. Products Corp. Bulletin 146.

New Electric Furnace. American Electric Furnace Co. Bulletin 151.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin 152.

"The Lectrodryer in the metallurgical industries," a new 4-page bulletin by Pittsburgh Lectrodryer Corp. Bulletin 155.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin 161.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin 154.

Turbo-Compressor data book shows how to calculate compressed air systems for a dozen different applications. Spencer Turbine Co. Bulletin 329.

High Temperature Fans. Michiana Products Corp. Bulletin 158.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin 156.

Catalog of heat treating materials. Heatbath Corp. Bulletin 322.

Standardized sizes of semi-muffle and pot-type furnaces are described and pictured in new leaflet by Dempsey Industrial Furnace Corp. Bulletin 354.

Use of pulverized coal in the metallurgical industries, equipment and designs, are described by Amsler-Morton Co. in Bulletin 361.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.

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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Line of Altitude Chambers in which products and materials may be tested at any given altitude, temperature and degree of humidity is described in new catalog issued by Cold-Hold Mfg. Co. Bulletin 549.

W. S. Rockwell Company has issued two new bulletins—an 8-page leaflet on oil or gas fired forge furnaces and a 4-page folder on standard pot furnaces. Bulletin 555.

"Why Heat Treat in Baths?" is the title of an interesting discussion by the Bellis Heat Treating Co. on the use of liquid heating media and the latest Edicurrent Furnaces. Bulletin 560.

Laboratory and tool room furnace. Mahr Mfg. Co. in new Bulletin 327.

82-page catalog describes in detail General Electric heat treat furnaces. Bulletin 380.

Furnaces for heat treating tools, dies and parts are described in new leaflet by Despatch Oven Co. Bulletin 362.

New booklet describes uniform case hardening up to .150" with controlled carburizing baths. American Cyanamid & Chemical Corp. Bulletin 372.

New book "Hardness" describes and evaluates hardness research of noted pioneers, methods of testing and testing instruments. Nitralloy Corp. Bulletin 366.

Four basic heat treating atmospheres are described in new booklet by Westinghouse. Bulletin 383.

The complete line of heat treating furnaces, burners and other equipment of this company is described and illustrated in new bulletin "D" just issued. Eclipse Fuel Engineering Co. Bulletin 483.

Vapocarb-Hump method for heat treatment of steel is the title of a newly-revised catalog issued by Leeds & Northrup. Bulletin 453.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.
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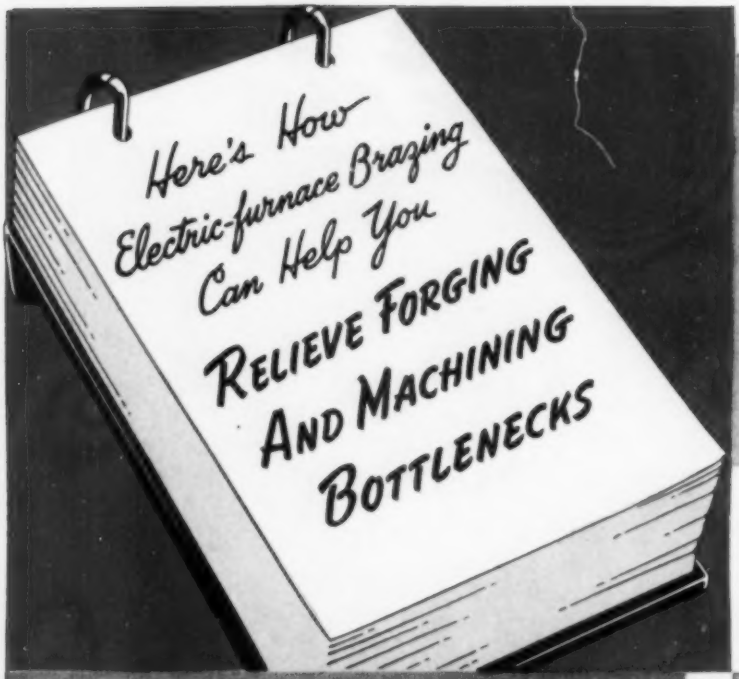
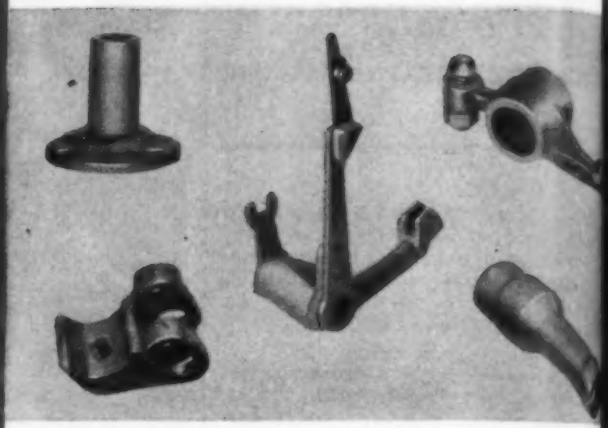
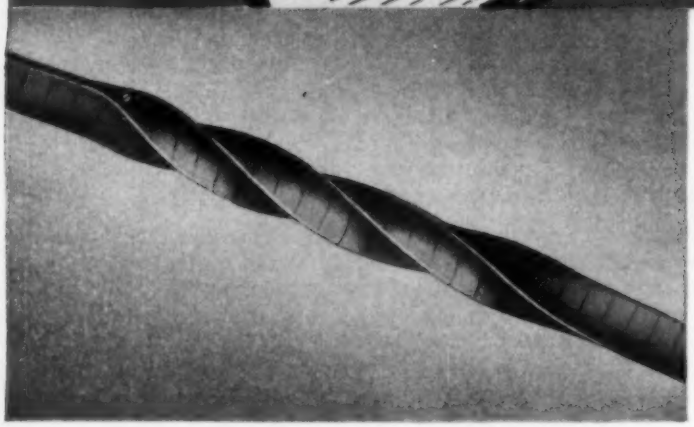
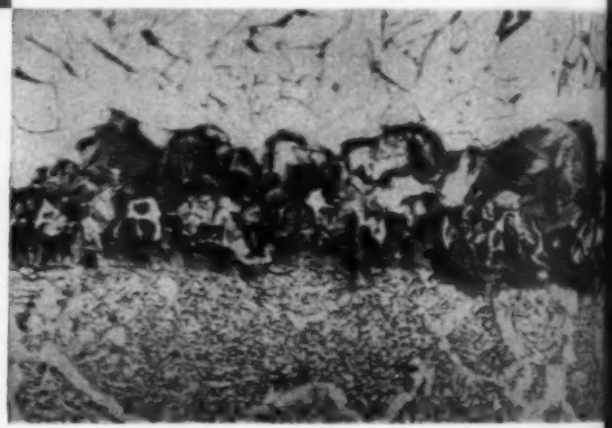




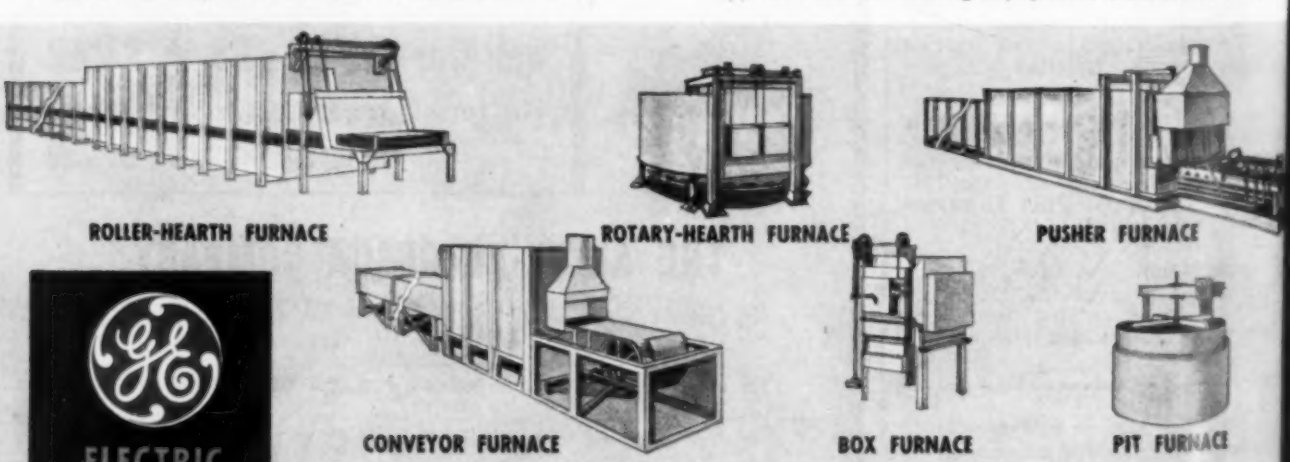
Many assemblies that are forged, cast, or machined from solid stock can be made more economically, and with great savings in scarce machine-time and materials, by utilizing less-critical stamping, screw-machine, and punching facilities and electric-furnace brazing. For example . . .



. . . bonds made by electric-furnace brazing have great strength, uniform tightness, and excellent appearance. This test bar, made of a series of ½-inch-square by ¼-inch-thick steel blocks copper-brazed together, resisted the tendency to shear even when twisted 360 degrees. Two reasons for this are . . .



. . . the alloying effect of the brazing metal with the parent metal and the knitting effect between the two parent-metal surfaces, shown by this photomicrograph of a copper-brazed joint between two pieces of steel of slightly different analysis. A typical furnace-brazing equipment consists of . . .



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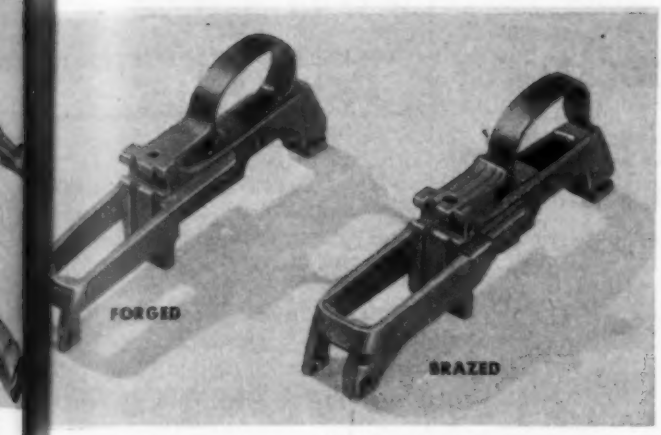
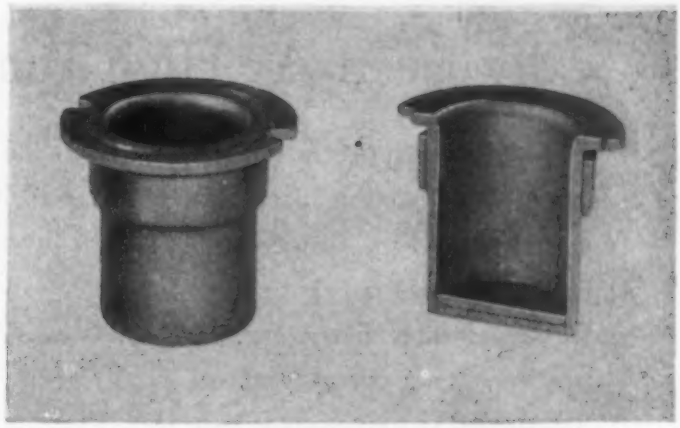


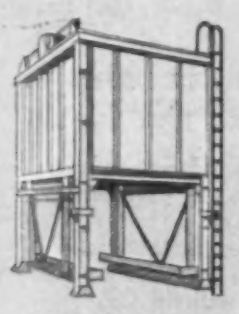
. . . this trigger housing for a .30 caliber carbine, formerly forged and machined, is now made of stampings, spot-welded together and electric-furnace brazed. No scarce forging capacity is used; machining time has been cut from 28.8 to 7.2 minutes, cost reduced 50 per cent. In another plant . . .



. . . this fuse adapter, which weighs 0.97 lb, was formerly machined from a 3.83-lb solid steel bar. Now it is made of two stampings, furnace-brazed together. Machining time has been cut from 0.23 hour to only 0.045 hour per part, scrap reduced from 2.86 to 0.84 lb. It has been proved that . . .

. . . an electric furnace with a cooling chamber, the necessary controls, and a device for supplying protective atmosphere. A roller-hearth furnace is recommended for large-scale production, a mesh-belt furnace for medium production, a box-type for small-scale production. It will pay you to . . .

. . . get in touch with one of our many industrial-heating specialists, who are located in principal cities. He will be glad to advise if one or more of your products can be redesigned for electric-furnace brazing. His recommendations are based on many years of training and wide experience.



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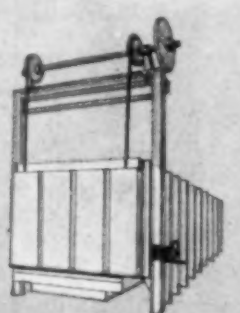

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R-846. Furnace doors of Amsco Alloy F-10, with welded-on handles of the same analysis. Lined with brick, they are used on furnaces in a steel mill.

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K-31. Work holder of F-1 Amsco Alloy. The lugs on the bottom fit over the ribs on a tray, and a hollow end propeller shaft fits over the four prongs. This alloy has the highest available strength at temperatures up to 2000° F.

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Metal Progress

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Trends in Alloy Steels

By A. B. Kinzel
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Conservation Division
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An appraisal of post-war developments based on a close acquaintance with the recent history of alloy shortages, scrap supply, and new steels developed for special ordnance purposes. This text is adapted from a talk before the Washington Chapter early in the spring.

THE PRE-WAR DEVELOPMENT of alloy steels, similarly to the development of other engineering materials, was predicated on obtaining a better performance-cost ratio. Primarily, this could be provided either by relatively expensive new alloy steels having unique properties which were well worth the cost, or by steels with properties identical to those previously obtained but of lower cost. With the advent of war conditions, particularly the limitation on the total amounts of specific alloys available regardless of cost, the criterion of advance and improvement changed. In a way this change may be considered a minor change, in that *pounds* of specific alloying elements were substituted for *dollars* in the prior concept. But the practical difference was intensely real, particularly when the anticipated supplies of alloy steel scrap were considered. As a result, our metallurgical problems were tackled from a new point of view and it is of interest to examine the developments to see how they now appear and what influence they will exert in a more normal economy.

Consider the steels in their usual categories of uses — that is, as-rolled or normalized structural steels, heat treated engineering steels, toolsteels, and high alloy stainless steels:

There have been few new developments in the low alloy, **as-rolled or normalized structural** steels. As a war measure, the peacetime use of such steels was largely eliminated. Moreover, these steels were already designed with low alloy content so that there was little to be gained by getting new combinations. Rather did the trend emphasize the use of those low alloy steels, already developed and well known, containing none of the more critical alloying elements. Possibly the most significant change in this direction was the substitution of manganese-titanium

for manganese-vanadium steels in certain types of ship construction, and the direct return to the more suitable manganese-vanadium steels as soon as the availability of vanadium permitted. Further of significance in this field is the expanded use of low alloy steels of chromium base and manganese base, due primarily to the lesser availability of nickel. As nickel is still not too readily available, it is too early to say to what degree this trend will be reversed, but some reversal is probable.

A word on the **weldability** of low alloy steels is in order. Under the war stimulus, research on weldability has been markedly intensified. The value of austenitic weld deposit material has been amply demonstrated. Methods have been evolved for specifying weldability of low alloy steels based on the Jominy hardenability test and the notch bend performance of the end-quenched bar at various distances from the end. These tests may or may not prove to be sufficient for the welding engineer but they should be of major aid to the steel industry and the specification engineer, particularly as they may be applied to heats of steel on the pouring platform, thus permitting rolling of the heat into heavier or lighter sections, or complete diversion of the heat, as the test may indicate.

Possibly the most important changes have come about in the heat treated steels, and of course the **National Emergency or NE steels** are the outstanding example. Among these, the 8600 and 8700 series have had by far the widest application and have been ideally suited to the circulating supply of alloy steel scrap — and still are — as well as to economy in the less available alloying elements. In this connection it might be emphasized that of all the usual alloying elements considered strategic at one time or another during the present war, only nickel remains under sufficiently rigid allocation as to present any problem, and even that element is much more plentiful than some short time ago.

Much has been heard of **hardenability factors** in connection with the newer steels; and Doctor Grossmann, the retiring President of ASM, has ably told that story. There is, however, one phase of hardenability that I would emphasize in connection with future trends. This depends on a metallurgical principle which, though old in lore, has now become both well founded and better appreciated. That principle might be enunciated as follows: "Maximum ductility in a quenched and tempered structure results when maximum homogeneity (generally 100% martensite) is obtained on quenching." This is true even though relatively high tempering temperatures are used in the final heat treating step. Obviously the lower the final tempering temperature, the greater the effect of the as-quenched structure, but it seems to be universally true that whether ductility be measured by static test, notched impact test or ballistic test, maximum ductility at any given tensile strength is correlated with homogeneous martensitic structure in the quenched condition.

This principle is of major import in connection with engineering design. Rarely has the engineer or designer felt secure in specifying steels of over 150,000 psi. tensile strength for normal service in machine parts, whether it be in automotive or other engineering applications. With the application of the knowledge gained in the development and use of engineering and ordnance steels in the past few years, they may now be assured of steels uniformly and regularly having adequate ductility at strength levels well in excess of the aforementioned 150,000 psi. — even use of design stresses of 200,000 psi. will not be uncommon.

The amount and type of alloy necessary to provide the required as-quenched structure in strong steels for such applications will depend on the nature of the quench and on the section at hand. Quenching technique in itself has made enormous strides of late and, coupled with the knowledge as to just how much alloy is necessary to get the desired result in any given section, makes for maximum economy in the use of alloy. Suitable steels obviously will not be lean in alloy content; the total alloy must be sufficient to provide a full martensitic structure on quenching. It is anticipated that this field of application will be well served by the steels in the 3100 (Ni-Cr), 4100 (Cr-Mo), 4300 (Ni-Cr-Mo) and 6100 (Cr-V) series, particularly if special addition agents are used and if tolerances on residual elements are broadened. The latter is to be expected in view of the scrap situation which will confront us for some time to come.

In steels of lighter section, or for less critical service, the NE steels as well as the 1300 (Mn) series should serve adequately. In this connection it might be mentioned that where low tempering temperatures are involved, the nature of the martensite obtained in the 1300 series — that is, the plain manganese steels — is much akin to that obtained in plain carbon steels whose normal manganese is one-half to one-third as much, and apparently lacks the homogeneity obtained with other alloy steels. This is true even in those quenched sections which appear to be through-hardened. This does not necessarily mean that the steels are unsuited for parts which must be

quenched and tempered but it does mean that the optimum in physical properties is not achieved. However, addition of relatively small amounts of nickel, chromium or vanadium, does permit the metallurgist to obtain optimum properties in through-hardened sections.

Therefore we may look forward to an alloy steel economy in which the older alloy steels are used at increasingly higher design stresses, with the newer steels fulfilling the need in smaller sections and intermediate strength ranges.

Much has recently been heard of the effect of boron and special boron-containing **addition agents**, and these additions have had sufficient use so that we are beginning to acquire experience with them. That they increase the hardenability (similar to the effect of the more usual alloy additions) is now well recognized and well demonstrated. However, there are certain features of the boron reaction which are not identical and warrant comment.

The addition of boron or analogous special addition agents results in a simple translation of the usual S-curve to the right with little change in its slope. Obviously, the inflection point of the Jominy hardenability curve is likewise pushed to the right. This means that if the alloy content of the steel, together with the boron content, is sufficient to through-harden in a given section, the boron effect is similar to the more usual alloy effect in that section. However, when such through-hardening is not complete, then the boron content has much less effect than does any one of the more usual elements. This is sufficiently marked as to warrant the use of boron only in those cases where the normal alloy content of the steel is already at a comparatively high level for the section. In other words, the boron addition is most useful in conjunction with important amounts of other alloying elements, and it plays but a small role in steels which are not thoroughly quenched or otherwise thoroughly through-hardened. This is consistent with the simple translation of the S-curve and with the postulate that the boron does not change the character of the martensite produced.

Thus, while we may expect to see an important use of boron addition agents in alloy steels, it should be recognized that the more usual alloys are still necessary as the base on which to build the analysis.

Another trend which is well worthy of note pertains to the role of **silicon in engineering steels.** Some years ago 0.15% silicon was a common level for them. Even before the war, a definite trend toward increased silicon content was evident. With the understanding brought about by Grossmann's concept of mutual reinforcement of multiple elements in a single analysis, and with increased experience, the silicon content has been further increased so that in many of the engineering steels it now approaches 0.35% — a value which is now commonly specified as a maximum. Still higher silicon contents have been used, particularly in some of the special steels, but as approximately 0.40% silicon is surpassed, additional mill problems present themselves.

It is probable, however, that the trend toward higher silicon in the more usual steels will continue, that the present 0.35% maximum will be

Twin Mounts of 5-In. Anti-Aircraft Guns Being Lowered on Turret-Base. Courtesy U. S. Naval Ordnance Plant, Louisville, Ky. (Westinghouse Operated)

closely approached in all engineering steels, and that in many instances this maximum limit will be raised. Where special deoxidizers which likewise promote hardenability are used — zirconium being outstanding in this respect — still higher silicon contents are common and are responsible for a more complete deoxidation, improved hardenability, and greater ease in achieving finer grain size. The pronounced trend toward steels of this type, evident in the last few years, will undoubtedly continue.

Carburizing steels are frequently classified with engineering steels. They represent an important special case. It is significant that in spite of the many attempts to obtain truly satisfactory carburizing steels of newer types, it is still broadly true that no steels have been developed which are as satisfactory as those based on nickel or chromium as the major alloying element, frequently supplemented with molybdenum or vanadium. Perhaps further research and development will lead to other improved steels in this field, but as yet this has not been achieved.

Toolsteels

In the toolsteel field the two categories of main interest are high speed steel and those toolsteels comparatively low in alloy. Wide substitution has occurred in the high speed steels with particular emphasis on the use of molybdenum in place of tungsten. Experience has shown that the steels of the nominal 6-6 (W-Mo) type have many uses and will undoubtedly fulfill an appreciable portion of future toolsteel requirements. On the other hand, experience has further shown that the 18% tungsten steels are better suited to a large portion of the applications, and these steels are rapidly returning to their normal position in the toolsteel field now that more readily available tungsten has been released for that purpose.

The role of vanadium in high speed steels has also been emphasized. Through the pre-war years there was a gradual trend toward increasing the vanadium in the 18-4-1 (W-Cr-V) type. With the wider use of the 6-6 (W-Mo) type containing close to 2% vanadium, the role of vanadium in providing wear resistance was better appreciated, and it is probable that the pre-war trend to increased vanadium now will be accelerated. In toolsteels other than the high speed steel type, the role of vanadium again has been emphasized. Its elimination, during critical months, resulted in less desirable toolsteels, so that when vanadium once again became available it was almost universally reinstated.

Stainless steels, due to the large amounts of alloys involved, have been the subject of much development and modification in the past few years. While from these experiences a number of detailed conclusions may be drawn, there are a few which stand out as major:

One of the obvious conclusions is that there is no substitute for chromium in stainless steels. Again there is no complete substitute for nickel in the austenitic steels for chemical applications. Furthermore, manganese, while useful as a substitute for nickel in many instances, is even more useful as a supplementary alloy. There has been and will continue to be an increasing trend toward higher manganese content in the older standard analysis such as the well-known 18% chromium, 8% nickel steels, and in the 25% chromium, 12% nickel types. The importance of nitrogen has likewise come to the fore; in it we have an austenite promoting element similar to carbon in all respects except that it does not carry with it many of the disadvantages of carbon, such as carbide formation and segregation and generally lowered corrosion resistance.

A whole new chapter has been written in high temperature metallurgy which properly comes under the heading of stainless steels but the time is not yet ripe to tell the story.

To summarize: While the present ratio of alloy steels to carbon steels (about 15% or perhaps a little more) will probably not be maintained when the production of war materials tapers off, it is probable that this ratio will continue to be somewhat in excess of the 6 or 7% current in pre-war years. The better understanding of the use of alloys will result in engineering designs for steel at considerably higher strength levels, and the more conventional alloy steels will maintain their position in the industrial picture. In addition, the leaner alloy steels such as the NE8600 and 1300 series will fulfill an additional role for use in smaller sections and in the lower strength levels. High speed steels of the 18% tungsten type will continue to be the main standby of the toolsteel industry but will be well supplemented by varieties containing sizable molybdenum percentages. Stainless steels will continue to expand in use with chromium as a major element, with nickel continuing to fulfill its important role in the austenitic types, and with manganese supplementing the nickel. In spite of the competition of plastics and nonferrous metals, we may well expect alloy steels to have a still more important place in the industrial picture — this as a result of their constant improvement and the better understanding of their properties.

Furnaces for Heat Treating Aircraft Parts of Aluminum Alloy

By Cecil J. Mayo
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Lockheed Aircraft Corp., Factory A
Burbank, Calif.

Elevator type furnaces, with electrically heated and recirculated atmospheres, developed many troubles from sagging doors and faulty hoisting device. They were rebuilt with a positive-action plunger hoist which carries the load at all times and whose motion is adequately interlocked with the door-opening mechanism. Problems now have principally to do with construction of work racks and provision of furnaces with high head-room, so long pieces or sheets can be heat treated while hanging end-wise.

SOLUTION HEAT TREATMENT of aluminum alloys is a subject of prime importance in the manufacture of modern aircraft. For this reason, the subject was one of the first attacked after the decision of the Lockheed management to build the former Vega Aircraft Corp., now Lockheed Factory A, into a major producer, and an investigation was therefore undertaken by the design engineering and the production departments. Specifications for heat treating were worked out wherein it was decided that heat treating would be conducted from the basis of metallurgical considerations alone and no compromises for production reasons would be permitted. *Control* of the process would be conducted by the engineering and inspection departments, but the type of equipment and manner of achieving results would be in the hands of the production department.

In the summer of 1940, when these decisions were made, there was very little high production equipment that would conform to the standards set. G. H. Prudden, assistant works manager, made an extensive inspection trip through the industry and came back, if not with the equipment procured, certainly with the needed designs firmly in mind.

At that time, the use of salt baths was the most effective method of heat treating duralumin. However, they had serious handicaps in their application to the problem at hand which did not seem to be capable of immediate and successful solution. These problems were admittedly not connected with the production of properly heat treated parts in a salt bath, but rather in the field of related operations. An adequate method of handling parts in and out of salt baths had not then been devised. Likewise the cost for dragout of a mixed potassium and sodium nitrate salt was a considerable item.

Finally, there was the question of labor. The summer climate of Burbank is scarcely that of the seashore, the hot weather lasting from May to October. Temperatures commonly exceed 90°, occasionally 100°. In one summer the tempera-

ture at Lockheed Airport reached or exceeded 105° every day for a period of three weeks. Southern California labor has always been averse to working under these conditions, and it was thought that a large salt bath installation in the center of the fabrication section would meet with serious objections from the workmen operating them and people in surrounding sections as well.

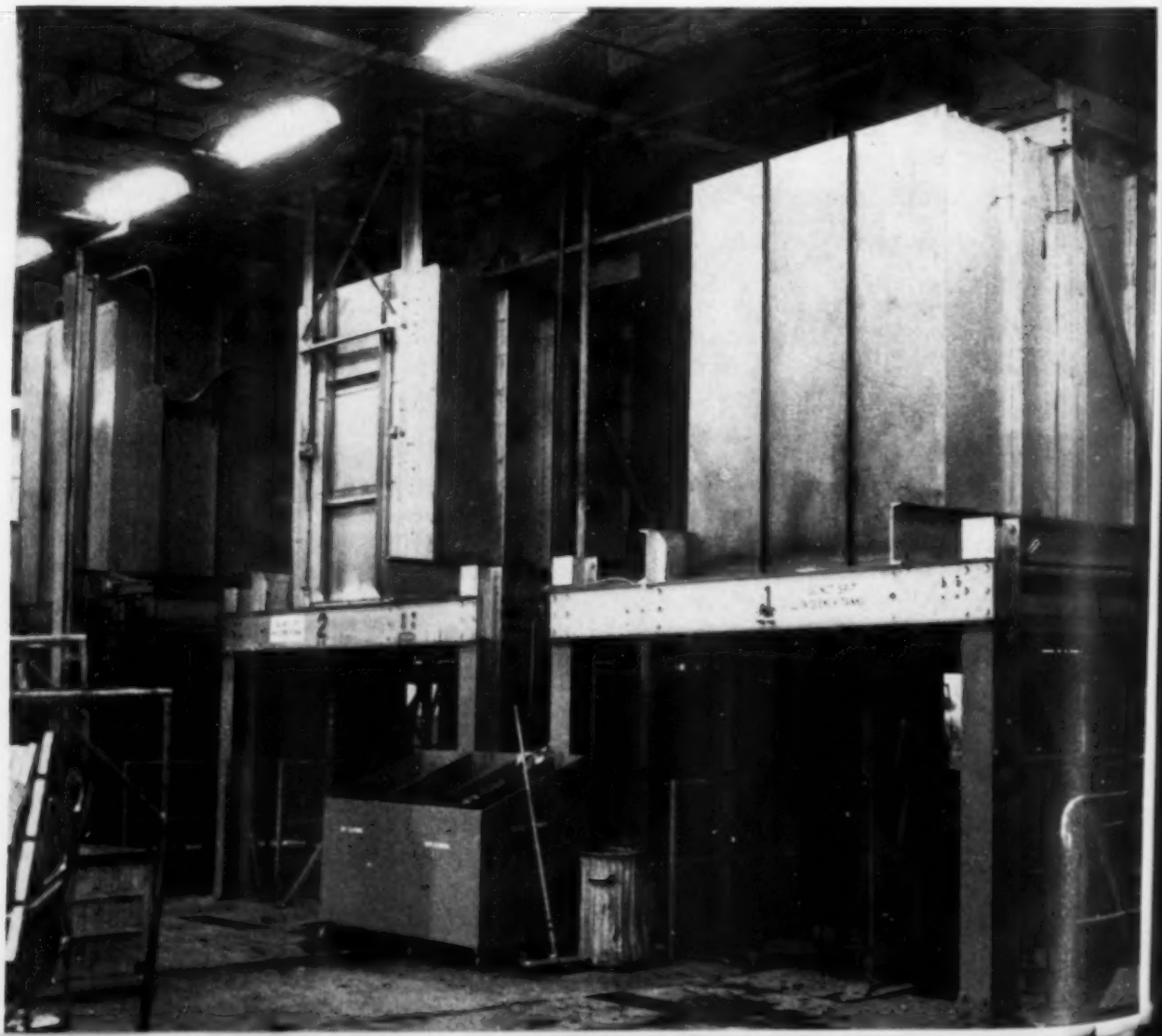
Circulating Atmosphere Chosen

For these reasons, it was decided by Mr. Prudden and his associates that the circulating air furnace type would be used for heating equipment. This decision has proven to be an extremely fortunate one. At the present time the aluminum heat treating division is in the most densely populated area of the plant. Over two-thirds of the employees are women, and there is little or no objection to summer operating temperatures. If we were to attempt to operate large salt baths with the present personnel, the problem of obtaining an adequate labor supply would undoubtedly be greatly intensified by the heat.

The plant engineering department was directed to set up specifications with the above principles as a guide and to procure and install the necessary equipment, and invite bids. These specifications called for furnace temperatures to be maintained throughout the furnace within ±5° F. of specified temperature, immersion in a still water quench-tank within 10 sec. after removal from the furnace, and the maintenance of suitable working conditions in the heat treat section and surrounding areas. The empty furnaces were to be capable of recovering their operating temperature within 20 min. after closing the furnace doors. Operation was to be entirely mechanical. The furnaces were to be capable of heat treating 8000 lb. of airframe parts in two 8-hr. shifts, the third shift to be available for emergencies.

Three firms submitted bids, but only one would guarantee meeting the 10-sec. immersion requirement. As a consequence, two furnaces of this make and design were purchased in the fall

Fig. 1 — Battery of Three Elevator-Type Furnaces at Lockheed Factory A for Heat Treating of Duralumin Parts. All have plunger type elevating mechanisms, and quench tanks with still water depressed in floor immediately below the furnace



of 1940 and installed in the spring of 1941. They were of the bottom-drop type with the quench pit directly below. This was an added advantage in space saving, as by this time the aircraft program had been advanced and the originally commodious plant area was shrinking alarmingly in the light of coming production schedules.

As is evident from the photographs reproduced on these pages, the rectangular furnace is set on columns clearing the floor by about 8 ft. Top and sides are closed in a steel box. Electrical resistors held by the refractory lining produced the heat, and temperature uniformity maintained by vigorous air circulation (fan and housing placed on top the furnace shell). Bottom of the furnace was closed by "doors", really a flat hearth split along the center line of the furnace. Each door was suspended from two-wheel trolleys at either end, and the furnace was opened by sliding the doors apart, one horizontally to the right, the other to the left.

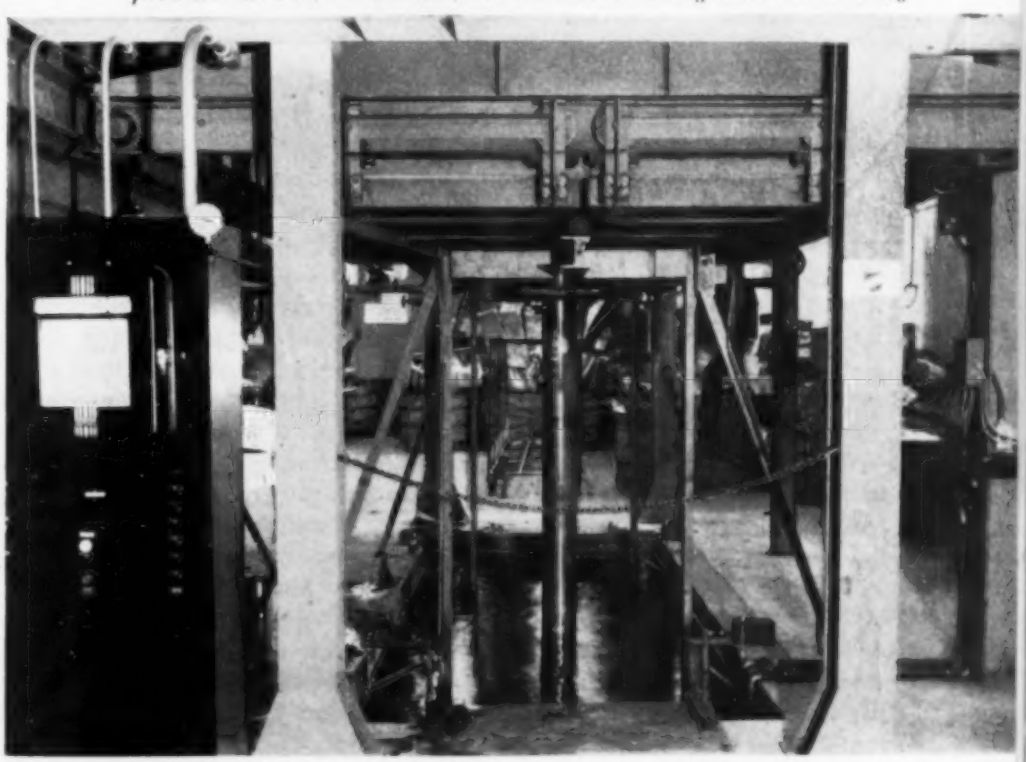
Our first two furnaces were put in operation in the spring of 1941. Control of the production was established by positioned samples in the furnace racks, by regular zone temperature readings, and by continuous spot samples of production parts from positioned locations in the load. Minor difficulties appeared at once, and corrections were applied as rapidly as possible. However, the furnaces continued to develop more and worse operational troubles as soon as the flow of parts became normal. As an example: Work racks, cages, or carriages of channel and angle iron construction were raised into the furnace (or lowered) by means of two chains passing over two sets of sprockets and attached to counter-weights. With slow operation, these chains rode the sprockets, but when the operation was speeded up to obtain less than a 10-sec. quench, they frequently jumped off. Also, the counter-weights caused several shut-downs in production, on one occasion by overshooting and jamming; the connection between one of the chains and the cage broke, letting one end of the fully loaded rack drop into the pit while the other end stayed up in the furnace!

Another cause of trouble in the heat treating operation was the distortion of racks on which parts were loaded. Various designs and types were tried and the trouble largely solved by use of X-4130 airplane tubing which was heat treated to the full hard condition before assembly and drawn by holding at the furnace temperature of 920° F. for 4 hr. after assembly. These racks gave an average life of 12 months and did not distort while in service.

Serious Operational Problems

The action of the door operating mechanism was jumpy and caused continual failures due to the rack carriage or cage not clearing the open doors. The carriage was abandoned, and a simple I-beam track support substituted, which was easily replaced when distorted. However, the difficulties steadily multiplied and the fully automatic features of the furnaces steadily disappeared. By the end of the first year's operation,

Fig. 2 — Close-Up of Hoist Plunger, Four Light Guide Rails to Carry Racked Load Into Furnace, and Horizontal Sliding Doors Forming the Furnace Bottom. Control cubicle is shown at left; air control valves on the building column at extreme right. Contactors and disconnects for heating power are alongside furnace above (not shown) and are reached by narrow balcony



the furnaces had become a maintenance and operational nightmare, with one or more major breakdowns per week. During this time the production schedule reached its peak and stabilized, but we were increasingly conscious of forthcoming trouble when the accelerated schedule of B-17F aircraft got into swing.

The saving grace during all this time was the furnaces' metallurgical performance; it continued uniformly good. The plant engineering department, charged with the responsibility of satisfactory design and maintenance of the equipment, re-opened the question of making a general revision of the furnaces and the procurement of additional equipment. The maintenance factor was further aggravated at this time by the shortage of alloy steel tubing for work racks, which resulted in much heavier and more easily distorted racks made of the only common steel that was available.

Before starting on any new design, recent furnace developments were investigated and it was decided to employ a new type of operational device known as the "Knapp-Lee Quick Quench Furnace", manufactured in Los Angeles. This type of operating device supports the load from beneath at all times, even while in the furnace. The elevator also locks at the loading and unloading level, which eliminates the objectionable factors encountered in the old type where the load could not be placed at the same level each time for loading and unloading.

It was decided to procure one new furnace of this type which would be installed first, and then rebuild the others. This new furnace was scheduled for delivery in early February, 1943, and foundation and quench pit drawings were prepared. However, before the work of installation could be started, one of our existing furnaces developed serious difficulties from the metallurgical standpoint and immediate rebuilding was decided upon. To do this, the operating hoist from the new furnace was diverted to the rebuild job.

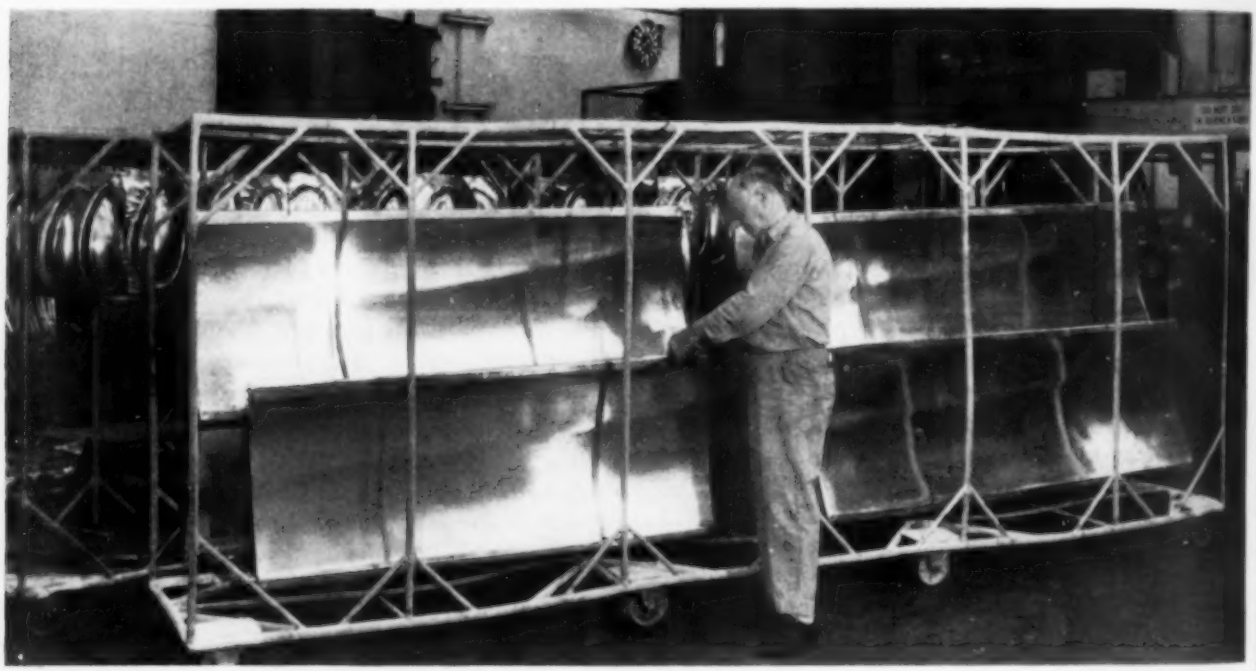


Fig. 3 — Two Types of Loads in Handling Racks — Very Large Long Parts in Foreground, Small Dished Parts at Rear. Rack shown is of ordinary steel and sags quickly even though it is much heavier than would be required with heat resisting alloy of good creep strength

In rebuilding the quench pit, it was necessary to increase the depth about 3 ft. During the time the pit was being deepened, the furnace was stripped to the shell, the electrical heating elements and bus bar sent to the shop for repair and alteration, new contactors installed and the doors rebuilt. The distribution of the heating elements was changed, the air ducts revised, an end door removed and the end closed solid. Places where the original lining had sagged, causing malfunctioning of the air distribution system, were braced into place and secured.

The hoist was placed 14 days after the furnace was shut down and re-assembly went forward as rapidly as possible. The rebuilding was complete in 22 days, and although some opera-

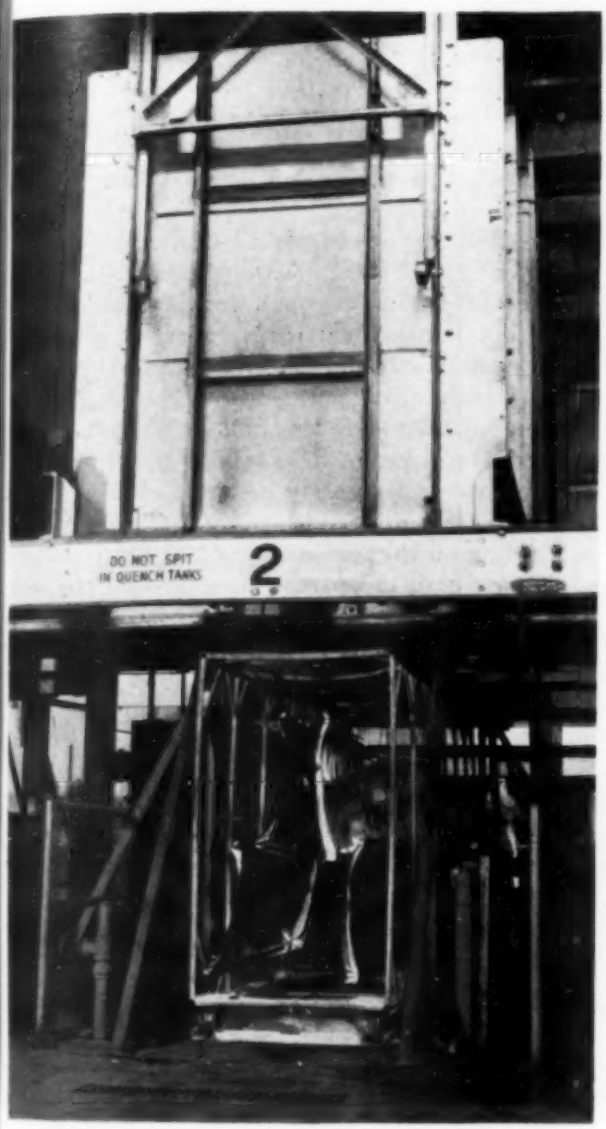


Fig. 4 — Rack of Large Parts, Such as Shown in Fig. 3, in Place at Floor Level, Ready to Be Hoisted Into Furnace as Soon as Bottom Doors Slide to Right and Left

tional trouble has since developed, the furnace is still in continuous operation and has fulfilled all of our anticipations.

The new furnace which was to be delivered would have superior temperature distribution, due to the improved design and installation of heating elements. In an effort to approximate this condition when rebuilding the old furnaces, the heating elements were regrouped with the low input 60-kw. unit on the lower side and the 90-kw. unit on the upper part of the walls. This resulted in low temperatures at the top of the furnace under low input or soaking conditions. When the 90-kw. heating element was used for low input, the bottom of the furnace was cold. The problem was solved by the addition of a proportioning controller which alternately energized the 90-kw. and 60-kw. elements under low input conditions; power was on 40% of the time on the 90-kw. and 60% of the time on the 60-kw. heater. This was so successful that a temperature distribution of $\pm 2\frac{1}{2}^{\circ}$ F. has been maintained since, and we have been able to increase the controller temperature to hold at the exact specified heat treating temperature with absolutely no reject parts due to blistering. Test samples are always within the allowable 5% limit on material variation, and well above minimum yield loads.

The new furnace which we know as No. 3 was not immediately available when the old ones were rebuilt, but the foundation was installed and preparations made to receive it. Great care was taken in this new furnace to avoid any waste in vertical dimensions, so the equipment could handle the longest part to be anticipated, when hanging with long dimension vertical. Clearances were as small as ¼ in. on sides and ½ in. in height. This furnace has now been in continuous operation for over a year, interrupted only for minor repairs made necessary by warping racks. A prime feature of this satisfactory operation rests with the positive action of the plunger hoist. Four light guides near the corners of the rack supporting grillage (or elevator platform) avoid trouble when entering the furnace under ¼-in. clearance. The floor-level locks are also clearly shown in Fig. 2.

Cycle of Automatic Operations

The normal cycle of all our rebuilt and new furnaces is now as follows:

With the elevator platform or grillage at floor level the loaded truck, or basket, is pushed on the receiving track and wheels locked. The starting button is pushed which opens the doors. When doors are opened, a contact is made which starts the hoist "up". After the load is in the furnace chamber, a limit switch trips, the hoist stops and another contact is made which permits the doors to close. All of these contacts are interlocked so that it is impossible to raise the load into, or lower the load out of, the furnace when the doors are closed or only partly open.

Temperatures are controlled by a single Leeds & Northrup Micromax Model S recorder-controller. This unit is equipped with a double set of contacts so that when the temperature approaches the control setting, the heat input is automatically reduced and when the control point is reached, the heat input is shut off. The electrical supply then goes on a time cycle as already described for the low input or soaking period.

When the heating and soaking cycle is completed, the doors are opened and the load drops rapidly to the surface of the water where it is momentarily checked, and then drops quickly into the water. As soon as the loaded basket clears the doors, they automatically close, thus conserving heat.

Loads are quenched in 7 sec. after the furnace door starts to open. This time can be varied from 2½ to 20 sec. by a simple adjustment. We have found that a 7-sec. elapsed time for total immersion gives maximum corrosion resistance to thin parts. Shorter times do not materially reduce copper segregation, and do increase the amount of hand straightening.

Checking and hand straightening of parts is required to some extent, but is not a problem except with parts having large surfaces and thin section. These troubles are being attacked by stretch-forming techniques while the flat material is in the SW condition immediately following a quench. These techniques are being applied to a greater and greater extent.

Cost Items

From the standpoint of operating efficiency, the furnaces, as now operating, are extremely satisfactory. The load possible per kw-hr. of current input varies from 2.46 lb. per kw-hr. to 4.6 lb. This variation is primarily due to the thickness of material and spacing of parts possible in the loads. A recent 72-hr. check on the lb. per kw-hr. when heat treating 0.032-in. sheet material averaged 3.36 lb. per kw-hr. input.

There is also a wide variation in man-hours per pound of material heat treated. On the new furnace procured in the spring of 1943, we have consistently heat treated 90 lb. of airplane sheet parts per man-hour. This is somewhat more than the first two furnaces due to the higher wattage available for heating-up periods. On this furnace, the recovery time averages from 14 to 17 min.; on the original two, it averages from 18 to 25 min.

The time from the moment of withdrawal of load to reloading is not included in the above figures and averages 2 min. per load. The incoming load must, of course, have been previously prepared and in position to load. Racks are loaded on the shop floor at one end of the furnaces and unloaded at the other. Incoming parts are stored at the loading end, and every effort is made to keep abreast of production to prevent congestion at this point. Heat treated parts are kept at the unloading end and passed on to the inspection department as rapidly as orders can be assembled. The production control department maintains close control at this point and there is seldom more than a 4 to 6-hr. bank of parts in the department.

In the line of future development, it is considered that several problems are of importance. The one of first thought is always that of racks on which the parts are loaded. The creep strength of mild steel, with which we now construct our racks, is very low at 920° F., the operating temperature. The racks sag slightly with each trip into the furnace and the sag is subsequently quenched into them. This forms a continuously accelerating cycle of distortion that is a constant source of trouble. It would be of greatest value if an alloy material could be made available for this purpose. The present war restriction on the use of any of the heat resistant alloys for high creep resistance in this temperature range is a very serious handicap, which has resulted in a marked decrease in furnace efficiency. Another thought is that a rack of welded steel tubing of something similar in properties to S.A.E. X-4130, aluminum-coated by the metal spray method, would be satisfactory. The weight per rack could be cut from the present 700 lb. to not over 400.

Another matter which is of prime importance is the heat treating of sheet stock and its subsequent forming while in the SW or freshly quenched condition. Ample low temperature refrigeration must be made available for such a scheme, in order to prevent age hardening while the sheets are awaiting their turn in the press shop. Forming also would be done largely by stretch-forming techniques.

In furnace design itself, the problem seems to center largely around the need for a greater interior height. End-quenching is a very necessary feature of the still water quench. Parts grow in length appreciably, by stretching under their own weight at heat treatment temperatures. Our new furnace will permit the end-quenching of a part 78 in. long. The furnace is 16 ft. long inside and 86 in. from track to roof duct. A furnace with an inside working height of 10 ft., which would take parts 9 ft. long, will soon be a prime necessity.

Door construction and seals are a matter that will still bear investigation. The water carried into the furnaces on each insertion of the rack warps the tops of the doors, which require continual maintenance and some furnace shut-downs for major repairs.

However, we are well satisfied with the principle of operation used and are looking forward to its use in the heat treatment of steel parts.

Cartridge Brass

Special Properties and Physical Testing

By L. E. Gibbs
Technical Advisor
Revere Copper & Brass, Inc.
Rome (N.Y.) Division

Some notes and precautions are given on the testing of cartridge brass, discussing particularly the three current methods of determining "yield point". It is emphasized that none of the common laboratory tests have any ready interpretation or close correlation with the performance of a cartridge in service, and therefore are most useful in verifying the uniformity of production in the brass mill, hour to hour. Under these circumstances the simplest test is preferred, and this is the hardness test. As a side remark the author states that creep strength is probably the best if not the only logical criterion for design of those copper-base alloys that have to carry steady loads; unfortunately very little testing of this sort has yet been done.

IN THE PREVIOUS ARTICLES in this series on cartridge brass the various terms for physical properties have been used without precise definition of their meaning, or of the methods for obtaining the numerical values. It is well, now, to spend some time on this, for in discussing the general subject in day-to-day work with users of copper alloys there have been a number of questions arising concerning test methods. Some of these will be discussed in the following. It appears convenient to subdivide this article according to the *form* of specimen used and the *values* determined from them, such as tensile, hardness, metallographic and special.

In testing for **tensile strength**, the most convenient specimen for rod forms seems to be one with a reduced center section and non-threaded ends. The reduced section is commonly 0.505 in. diameter with a taper of 0.002 in. approximately to the center. Most specifications recognize that rods over 1½ in. in diameter are cold worked but little at the center and an axial specimen would not represent the approximate average of the entire bar, so the specimen axis on large rounds is at ¼ the diameter of the original sample.

For plate or strip specimens a reduced section is characteristic (except strip less than 1 in. wide and light gage, say 0.010 to 0.015 in. and under, which may be pulled full size). An important tonnage of strip and plate is made for ammunition components as well as for cable wrapping, shim stock, radiator metal, diaphragms, flexible hose and the like, so it may be well to mention several points in the technique of "pulling" such specimens. The thinner the gage, the more difficult it is to hold the sample in the grips without inducing failure at the grips, and to localize the "break" in the center somewhere between gage points. Commercial types of grips used for textile or similar testing, wherein the material is wrapped around a block before gripping, will be of great aid. Other types

can be used but require very fine serrations on the jaw face, must be kept spotlessly clean and the sample lined up perfectly to prevent stress concentrations and breakage at the wrong point.

If a large number of samples of similar size and gage are to be tested, it will pay the laboratory to prepare a die to blank a reduced section. The die should be made with close enough clearance so the edges will not tear, else fractures at the tears will likely occur. Another method, also applicable to heavier specimens, is to use a contour milling cutter; the best type mills both the ends and the reduced section, and the cutter is run across a number of specimens clamped together to produce the profile. In either method it is preferred practice to stone the edges of the reduced section for a smooth surface.

Tension Test on Strip, Being Made in Small Amsler Machine (Bell Telephone Laboratories)

Interpretation of results of tensile tests is a straightforward job in most cases. However, numerical values for heavy sections will be lower than for light sections (in cold worked material particularly) because, as mentioned before, the effect of cold working will not penetrate uniformly through the entire cross section, being most marked at the surface.

All in all, the tensile strength is probably the most reliable value for specification use or for determining the physical condition of *cold worked materials* of all copper-zinc alloys. This does not mean it should be required for *all* acceptance work, since other values may serve equally well or better, and be less of a burden in the testing laboratories of both consumer and supplier. Examples are Rockwell hardness for tubing and commercial tempers of strip, and grain size for annealed tempers of tubing and strip to be used for subsequent cold forming.

In connection with specifications, it might be mentioned here that it is impractical in the brass industry to record properties by heat numbers. The simple truth is that castings may be as light as 200 lb. or as heavy as 3000. (The 2000 and 3000-lb. cakes for cartridge brass are typical of wartime plants, and not of peacetime.) To keep track of each casting during subsequent processing not only would be a tremendous burden, but is also considered quite unnecessary since it serves no useful purpose. A previous article has mentioned the systems enforced to keep alloys segregated by composition and to insure material up to standard.

Elastic Properties

Routine checking of the 0.5% yield strength, most commonly called for, is done during the tensile test, either with autographic, optical or mechanical strain gages of various types. A discussion of them or their merits does not belong here, but the instrument manufacturers can help a great deal in defining their capabilities and field of use.

The various methods and numerical values used to describe the "elastic properties" can provide subject matter for a very considerable tome, for which we have no space. However, a brief description of these methods and some of the advantages and disadvantages seems quite pertinent:

Yield Strength is defined by American Society for Testing Materials in Specification E6-36 as "the stress at which a material exhibits a speci-

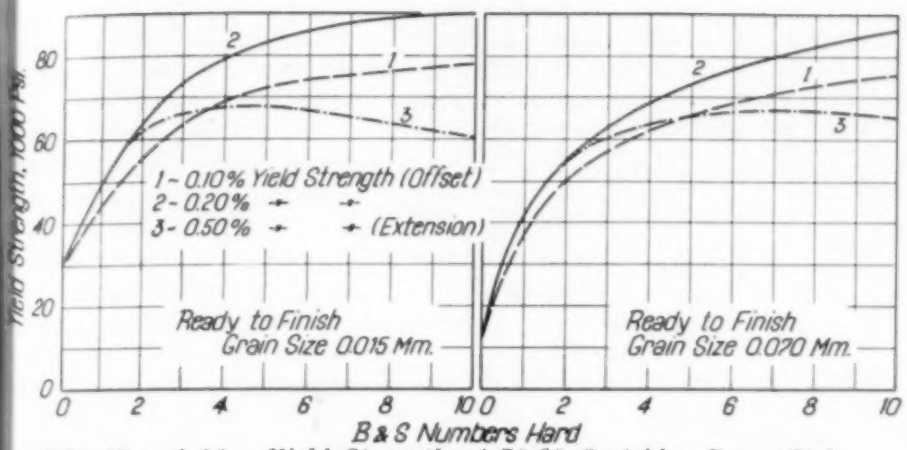


Fig. 25 and 26 — Yield Strength of 70-30 Cartridge Brass Strip as it Varies With Method of Determination, Temper (Cold Work) and Ready to Finish Grain Size (Fine at Left, Coarse at Right)

Numbers are consecutive, from former articles in the series.

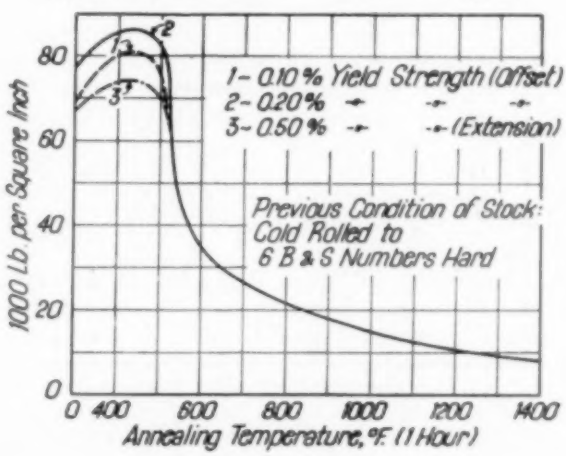
fied, limiting, permanent set". The Federal Specifications Board is of the same mind but uses different language in Specification QQ-M-151a: "The load per square inch of original cross sectional area which causes a specified set, as measured by the offset method or a specified extension under load" (paragraph 37d). It also mentions two methods used to determine the value for yield strength. The "offset" method shown in Fig. 28, page 702, requires a stress-strain curve and the numerical value represents the intersection of a line which is parallel to the curve's tangent at a distance of 0.1% (or 0.2%) of the original gage length. It is assumed that such a value represents the approximate permanent set of 0.1% (or 0.2%); the reader should refer to the two specifications for detailed descriptions. The second, or "extension under load" method described in the Federal specification, is merely the stress required to produce 0.5% extension under a given load, most commonly the 0.5% yield strength.

Elastic Limit is "the greatest stress which a material is capable of developing without a permanent deformation remaining upon complete release of the stress", according to A.S.T.M. E6-36. The Federal specification is more specific, stating in paragraph 37a that elastic limit is "the greatest load per square inch of original cross-sectional area which, when removed, has not caused a permanent elongation exceeding 0.00003 in. per in. of gage length". Other methods, such as "Johnson's elastic limit" and the "apparent elastic limit" mentioned in previous articles, attempt to determine the value through an approximation which is good enough for general use.

Proportional Limit, according to paragraph 37b of Federal specification QQ-M-151a, is "the greatest load ..... for which the elongation is proportional to the load".

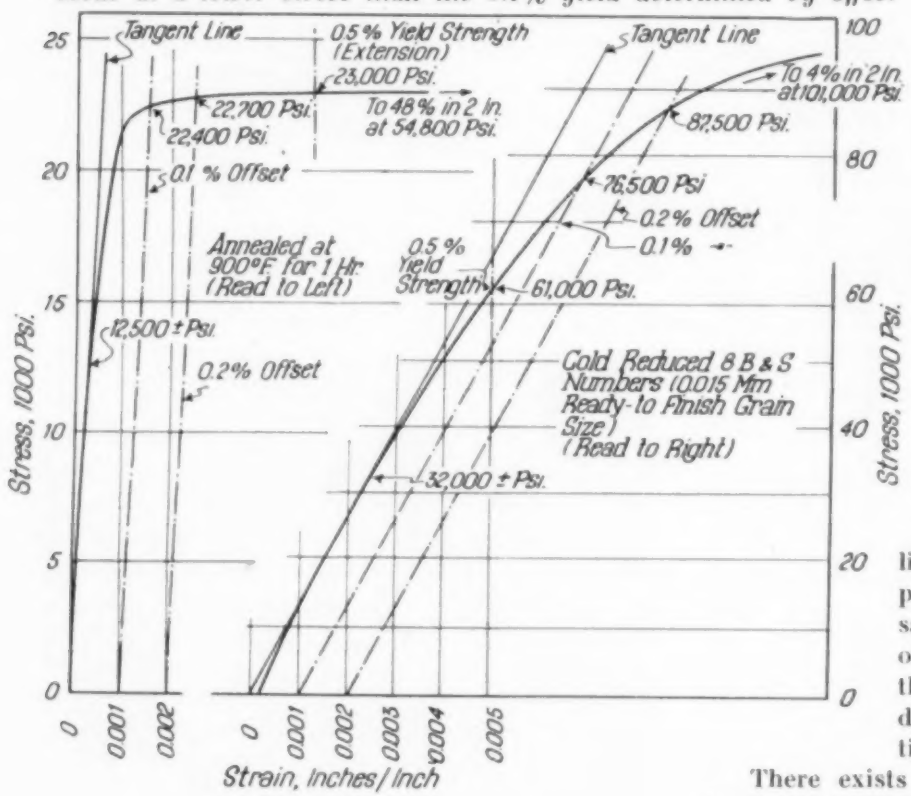
While the definitions are simple enough, the meanings or utility of the various values obtained are not readily apparent, nor are there any simple methods for determining these values when utmost accuracy is required. For specification work and the acceptance of material, the 0.5% yield strength is widely used. It is easy to determine. It is, therefore, an eminently practical test from the brass mill's standpoint, especially if a tremendous number of tests are required, as is true in wartime. On the other hand it has its limitations and is of very doubtful value in showing a designer the useful elastic properties of cartridge brass, copper or many another of the extremely ductile copper base alloys. It does not retain a constant relationship to the tensile strength as the temper varies. Neither does it necessarily show a fixed relationship to tensile strength as the alloy varies. As examples, in hard drawn copper the 0.5% yield strength is nearly the same figure as tensile strength, but in an aluminum-silicon-bronze the value is considerably lower in proportion (see Table VI). For comparisons in cartridge brass see Fig. 6 and 7 in the August 1943 article and Fig. 25, 26 and 27 herewith.

Fig. 27 — Annealing, Even at Low Temperatures, Erases Most of the Difference Between the Various "Yield Strengths"



The "offset" yield

Fig. 28 — Typical Stress-Strain Curves for Annealed Cartridge Brass (at Left) and for Material Cold Rolled 8 B. & S. Numbers Hard. Yield strengths by offset and extension are about the same for annealed brass. For hard drawn material 0.5% extension may occur at a lower stress than the 0.1% yield determined by offset



strengths are somewhat more consistent in their relationships to the tensile strength, as Fig. 25 and 26 show (and sometimes are more conservative, as they are for copper). However, the offset method has at least one objection and that is that it depends upon a tangent being drawn, and it is not always an easy thing to draw it accurately. (While speaking of tangents, the "proportional limit" suffers the same handicap and furthermore seems to show lower values, generally, as the sensitivity of the extensometer increases.)

The troubles of determining elastic properties stem from the smooth stress-strain curves typical of many non-ferrous alloys, including those of copper as well as of aluminum and magnesium. (In copper alloys there has not, until relatively recent years, been a demand for accurate stress values because of the large tonnage in non-stressed parts. In strong aluminum alloys the condition is just the reverse.)

The curves in Fig. 28 show the actual stress-strain curves for soft and hard cartridge brass strip; the strain increments are the same, but the stress values are not, which provides a longer curve for the annealed material. The various points under discussion are illustrated. It is apparent in the hard sample at the right that a question of judgment exists as to the exact tangent position, but since our experience indicates the curve should have been straight at the lowest portion, rather than curving to the right as shown, the tangent was so drawn and the strain values measured from it. The "proportional limit" (12,500 ± and 32,000 ± psi. for the annealed and hard samples respectively) is obviously much lower than any of the other tensile properties as defined in the usual specifications.

There exists a well-founded belief that a stress required to produce a very small but definite permanent set is probably a good representation of the stress the material can be designed for, such as the "elastic limit" of the Federal specification. However, the basic fact seems to remain that the *creep strength* is the ultimate in the determination of load carrying ability. It is to be hoped that some day the necessary considerable time and skill will be spent on correlating the relationship between the elastic limit and creep strength so that the design figures be known, and to find a relatively quick test to reveal the true elastic properties.

Table VI — Variability of "Yield Strengths" With Temper and Alloy

Property	Electrolytic Copper		7% Al, 2% Si Bronze, Cold Drawn 10%
	Annealed	8 B. & S. Numbers Hard	
Tensile strength	33,500 psi.	56,900 psi.	95,000 psi.
Elongation in 2 in.	55%	4%	25%
0.5% yield strength (extension)	9,600 psi.	54,000 psi.	54,000 psi. *(a)*
0.2% yield strength (offset)	8,600 psi.	53,000 psi.	63,000 psi.
0.1% yield strength (offset)	7,700 psi.	48,000 psi.	50,000 psi.

(a) The anomaly that 0.5% value is less than the 0.2% value is explained by a more inclined slope of the early tangent portion of the stress-strain curve for this cold worked material. See Fig. 28.

More in the way of commentary are the figures in Table VII, which include creep rates at 300° F., but since no softening took place after 5040 hr., they are judged to be comparable with room temperature values.

Elongation and Reduction of Area

The commonest gage length is 2 in., but 8 and 10 in. are also used for small rods and light metals respectively. In this connection, many of the Government specifications, for rods particularly, call for elongation "in 2 in. or four times the diameter". This becomes important on small sizes of very hard drawn rods. Numerical values in the order of 10% elongation for ½-in. rod may not be reached on ⅛-in. rod of similar tensile strength. The effect of specimen size on elongation is well established by metallurgical work, and this accounts for the condition, but some specifications still do not recognize it as completely as they should.

It will be found that some copper alloys "neck down" much more than others, which not only affects the reduction of area (the more contraction the higher the numerical value), but also the elongation. Much of the stretch in copper and copper-zinc alloys (also silicon bronze and cupro-nickel) takes place in the necked down area. Consequently, the testing engineer should observe the rule which allows a retest when the break is outside of the middle third of the gage length, else elongation values are apt to be low. The beta-containing materials, such as free cutting brass rod and Muntz metal, do not show this to such a degree as the alpha alloys which are our principal concern.

Very probably the values for elongation and reduction of area will together provide a good value to the ductility of copper base alloys. For example, Fig. 8 and 9 in the August 1943 issue, illustrate two pertinent points: *(a)* Elongation is high in the annealed condition, about 75%, and so is reduction of area, and *(b)* the reduction of area decreases at a slow rate with cold work. Other alloys such as Grade B silicon bronzes and 70-30 cupro-nickel show similar effects — that is, reduction of area of 85 to 90% as annealed, with high elongation, and even less decrease in reduction of area by cold work than is observed in cartridge brass. These alloys are superb for use in cold heading operations.

Table VII — Creep Strength at 300° F. Versus Yield Strengths of Cartridge Brass Rod Cold Drawn 37% From Fine Grained Material

Property	A Single Test *(a)*	Expected Range
Tensile strength	86,000 psi.	85,000 to 90,000 psi.
0.5% yield strength (extension)	62,000	60,000 to 65,000
0.2% yield strength (offset)	—	65,000 to 70,000
0.1% yield strength (offset)	—	58,000 to 65,000
Creep strength *(b)*	24,000	—

(a) From "Creep Characteristics of Some Copper Alloys at Elevated Temperatures" by H. L. Burghoff, A. I. Blank and S. E. Maddigan, *Proceedings* A.S.T.M., 1942, Vol. 42.

(b) 0.01% per 1000 hr. at 300° F.

Hardness

Brass mills have settled upon the Rockwell hardness test as standard for the majority of their products and have any number of good reasons for it. The test methods are well described, as well as the limitations on the various scales of hardness. We do not like to use the F scale above F-90 hard, preferring the B scale, nor do we feel that above B-95 we are obtaining true readings. On the soft side F-20 to F-25 is representative of dead soft copper and we rarely go lower. Neither do we use under B-20. For light metals the superficial scale is popular and, while it may not show absolute hardness on copper 0.005 in. thick, when used with diamond anvils it is successful in controlling the temper of production lots so that subsequent fabricating can be done without failures.

It should be mentioned that tubes should be cut open and the test made on the inside for consistent results — except on small bores when the penetrator will not fit, when a close fitting steel plug is frequently used to support against collapse when tests are made on the outer surface. Furthermore, the penetrator will bulge rounds of small sizes, if F or B scales are insisted upon, which means the surface should be filed flat for accurate testing. Another special condition is a wedge shape or angle bar which must be fitted to a supporting block which corrects the surface so that it is absolutely normal to the penetrator; very serious errors can result from testing angle sections without correction.

Of the various other methods, the Vickers machine is expensive but it has the advantage of a constant scale which is directly comparable for hard and soft ranges. Brinell hardness is used for heavy plates, say above ¼ in. thick, or for large sections where adequate support can be had around the ball penetrator and its accuracy

is unquestioned. For sections which are so light that anvil marks are noticeable or for others not large enough in area for ball support, we feel the Brinell method is unreliable. Specifications not recognizing these limitations are believed to be inadequately drawn up, because large amounts of material are made which do not fall within the scope of the test.

A hardness conversion chart relating the various Rockwell scales, the Vickers diamond pyramid, and the Brinell 10-mm. ball is given in *Metal Progress* Data Sheet No. 62.

Metallography

On pages 704-A and B are shown in color various structures of common copper materials, including cartridge brass; these give a good comparison of the constituents. The beta brass in Muntz metal types should not appear in cartridge brass, as is obvious from the constitutional diagram. The specimen of oxidized copper is very rich in oxides, being made specially to show the typical color and structure in an exaggerated way. Obviously oxide should not be found in cartridge brass, even though it will appear in small amounts in tough pitch electrolytic copper and in the other commercial coppers which have not been completely deoxidized — where it is not regarded as a detriment.

Skill plays a great part in the preparation of metallographic samples. Standard etching reagents are well covered in Metals Handbook, page 1471 of the 1939 edition.

Standard grain sizes have been referred to in the article in this series appearing in the June 1943 issue of *Metal Progress*, and are as shown in the A.S.T.M. Specification E2-39T (reproduced in *Metal Progress* Data Sheet No. 56 — also on page 990 of this issue).

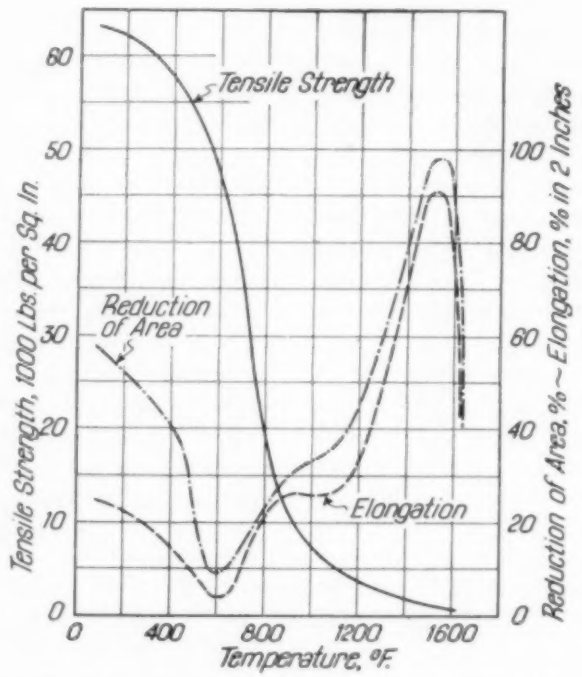


Fig. 29 — Short Time Tensile Properties of Cartridge Brass, Previously Cold Drawn 20%, From Room Temperature to 1600° F.

Special Properties

Miscellaneous Physical Constants are shown in Table VIII at the bottom of the column at left.

Impact strength is high for cartridge brass at room temperatures and, in common with other copper base alloys, the values do not decrease with decreasing temperature. Charpy tests on annealed material are about 85 to 89 ft-lb. from room temperature to —112° F.,★ whereas Izod values are about 66 to 79 ft-lb. from room temperature to —292° F. (tensile strength varying simultaneously from 51,000 to 73,000 psi.).† It appears, therefore, that as the temperature decreases the tensile strength increases, but impact properties do not suffer appreciably at sub-zero temperatures.

High temperature strength is poor for cartridge brass since the general rule is that a time and temperature which causes recrystallization will also reduce the creep strength to so low a figure as to be of little use, practically speaking. Working stresses for this class of alloy are set up in the A.S.M.E. Unfired Pressure Vessel Code, Table U-3, and limit temperatures to 500° F. with allowable stress decreasing as temperatures rise from 150 to 500° F. The short-time physical properties at various temperatures are shown in Fig. 29.

Table VIII — Miscellaneous Data on Cartridge Brass

Melting point	1750° F. or 955° C.
Coefficient of expansion —	
per °C. from 25° to 300° C.	0.0000199
per °F. from 77° to 572° F.	0.0000111
Electrical conductivity	27% of International annealed copper standard
Thermal conductivity per sq.ft. per ft. per hr., per °F.	70 Btu.
Density (lb. per cu.in.)	0.308
Modulus of elasticity,	Approx. 15,000,000 psi.
Endurance limit — soft	17,000 psi.
Rod, cold drawn 50%	22,000 psi.
Strip, 4 B. & S. numbers hard	19,000 psi.
Strip, 8 B. & S. numbers hard	22,000 psi.

★"Effect of Low Temperatures on Metals and Alloys" by H. W. Russell, Joint A.S.T.M. and A.S.M.E. Symposium on Effect of Temperature on the Properties of Metals, 1931, page 486.

†"Some Properties of Copper at Low Temperatures" by C. S. Smith, *Proceedings* A.S.T.M., 1939, vol. 39, p. 642.

Kodachromes of Copper Alloys

Research and Development Laboratory, Revere Copper and Brass Incorporated

Photography by R. D. Destito
Samples prepared by W. Jenks
All magnified 75 diameters

—Fig. 30
Cartridge Brass, Etched With $NH_4OH + H_2O_2$. Typical Annealed Structure; Twinning Apparent

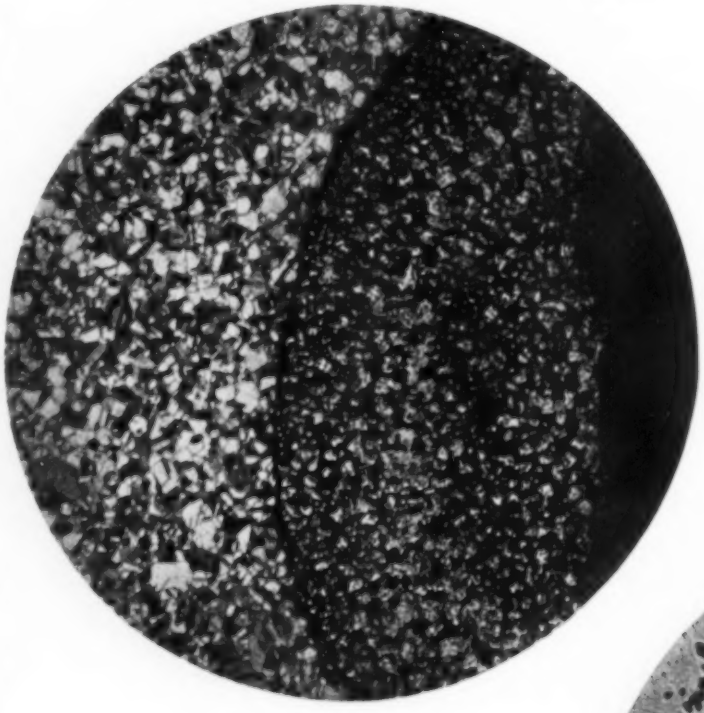
Fig. 31—
Muntz Metal, Etched With Ferric Chloride, Which Darkens Beta Phase But Does Not Attack Alpha Phase

—Fig. 32
Muntz Metal. Same Sample as Above, Etched With $NH_4OH + H_2O_2$ to Show Beta Phase Lemon Yellow

Kodachromes of Copper Alloys

Research and Development Laboratory, Revere Copper and Brass Incorporated

Photography by R. D. DESTITO
Samples prepared by W. JENKS
All magnified 75 diameters



— Fig. 33
Dezincification. A Typical Red Copper Plug Re-Deposited in the Corrosion Pit in the Yellow Brass. (Etched Microsection)

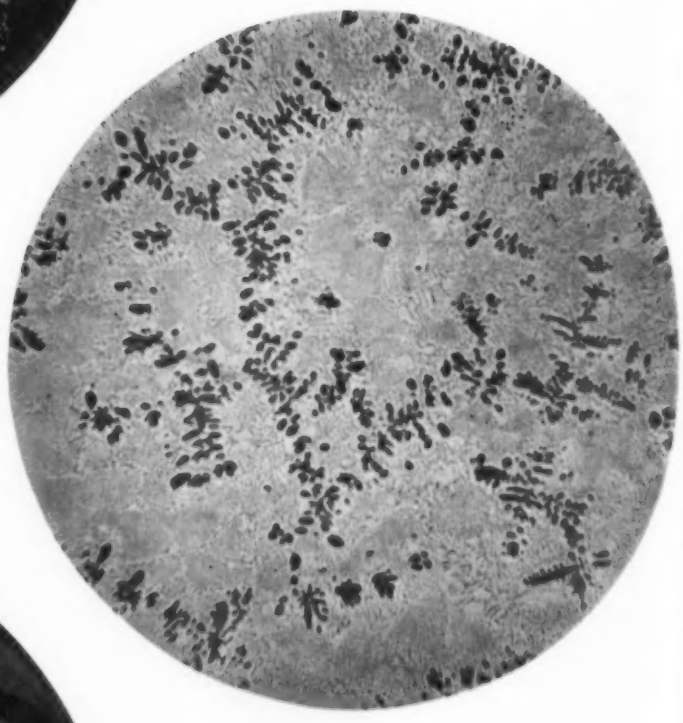


Fig. 34 —
Unetched Sample of Copper, Designedly Made With Very Large Amount of Oxide. Dendritic Structure Is Typical, as Well as the "Finger Print" Appearance of the Eutectic (Copper and Copper Oxide) in the Background

— Fig. 35
Oxygen Free, High Conductivity Copper, After Exposure to High Temperature. Very Large Grain Size. Micro Slightly Underexposed

The Selection of Steels

Used in the Rolled or Drawn Condition

Part 1—Plates

By John H. Frye, Col.
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Research and Development Service
Office of Chief of Ordnance
Washington, D. C.

This is a part of a lecture, one of an educational course presented last winter by the New York Chapter. It is not to be regarded as the official viewpoint of the Ordnance Dept., U. S. Army, but as representing Col. Frye's personal opinions. In it he outlines the factors that underline the intelligent selection of any steel for a given duty, emphasizing that it also requires the cooperation of designer, production man, metallurgist, and purchasing agent. Applying these principles to the selection of steel plate, the author pays most attention to the possibilities of low alloy, high tensile steels.

IN THIS SERIES of lectures organized by the New York Chapter, ASM, I have been asked to discuss the selection of steels upon which no heat treatments are applied after receipt from the mill. Stainless steels, which fall into this category, are to be described by another lecturer, so we will confine ourselves largely to the plain carbon steels, almost eliminating alloy steels, since only rarely should the latter be used unless subsequently heat treated. (Of course, there are applications where alloy steels are quenched and drawn at the mill, and machined or fabricated into parts; likewise there are alloy steels, generally plates, which are normalized at the mill to meet specified minimum physical properties upon which no further treatment is performed. Then there are the few isolated conditions which justify the use of an untreated alloy steel.)

Under existing conditions as to delivery it is necessary for the purchaser to allow more or less latitude in grades, sizes and shapes of steel. Availability of the *adequate* material is often the predominant factor, and in such cases, it is especially important that the metallurgist exercise judgment. There is the temptation to respond to pressure from the sales manager or superintendent and authorize the use of an inadequate material so that delivery schedules can be met. There is also the temptation to be hidebound and insist willy-nilly upon the original material specified. Either course would better be replaced by common sense.

This reminds me of a story told by Karl Compton, the physicist. His sister living in India was having a simple electrical installation done by a native electrician. He troubled her so much for detailed instructions that at last she said irritably, "You know what I want; just use your common sense and do it." The electrician, salaaming politely, replied, "Madam, common

sense is a rare gift of God. I have only a *technical* education."

Common sense is truly a gift of God, but if common sense alone could have made the installation it is unlikely that the electrician would have been called. A hundred years ago common sense told people that Fulton couldn't drive a boat without sails. It clearly "proved" that blowing cold air on molten iron would chill it, so that Mrs. Kelly had a brain specialist examine William when he first made steel in a converter. Common sense may play tricks, but when combined with sound technical knowledge and tempered with ingenuity, it is the backbone of American industry. Let us not persecute "common sense" by burdening it with preconceived notions, convictions or prejudices.

It has been said that wars bring out the worst in men, and the best in scientific development. Certainly the science and techniques of metallurgy have advanced tremendously during the past four years. Perhaps the greatest advance of all, in the way of engineering, has been the close and harmonious cooperation of designers, plant engineers, metallurgists and procurement personnel. This coordination is the result of necessity, but it is hoped that the habit will be strong enough to endure after the peace. It is predicted that intercompany engineering coordination *must* become an everyday fact for successful competition. The field of engineering has become too broad and too complicated for restrictive practices.

By the same token, I believe that common sense, even combined with metallurgy, is not sufficient for the proper selection of steels for given parts. It requires the close and harmonious cooperation of designers, plant production engineers, metallurgists, and procurement personnel. Each of these is a specialist in his own field. Seldom do they feel conversant with the other fellow's problems; seldom do they wish to appear ignorant of them. Yet *combine* their talents before work begins on the drafting board and the result will be better engineering, lower costs, fewer service failures, and a degree of efficiency heretofore unattained.

In the selection of steel for a specific application it is necessary to consider three factors — *(a)* service functions and stresses, *(b)* method of fabricating, and *(c)* the finished shape and dimensions. The grade or commodity selected must be congruent with all three. The starting point, then, is to consider individually the properties or characteristics which will be required of the steel, usually in some combination, for a given application. The commonly required properties are strength, ductility, toughness, grain size, wear resistance, corrosion resistance, reliability, and workability. Each of these will now be considered briefly and in general terms.

Strength

(a) Tensile Strength and Yield Strength. Many engineering formulae use tensile strength in determining design factors. That was entirely satisfactory in years past, since steels of those days had a fairly uniform ratio of yield to tensile. This is no longer true. Many newer compositions have a much higher yield as compared to the tensile strength. With the emphasis now on mobility and reduced weight, engineers and designers are tending toward the use of yield strength in engineering calculations.

(b) Shear Strength. This may be figured as approximately 50% of the tensile, or 60% of the yield strength in tension. In view of the increased ratio of yield to tensile in modern steels, the latter is preferred.

(c) Bending. Strength has nothing to do with bending, although bending has a great deal to do with strength. By that it is meant that bending stresses are frequently combined with other stresses and considerably decrease tensile, torsion and fatigue limits. Increased cross-sectional area of the part, better supports, or less span between bearings are the only cure for unwanted deformation from bending.

(d) Torsion (encountered usually in the transfer of energy, delivery of power, or to provide for resistance to rotational stresses). Resistance to torsion is essentially one of section modulus. For shafting purposes lighter weight may be obtained by using tubing as the shaft. A tube shaft can be stronger than a solid bar, but if shock loads are involved a tube shaft will fracture while a solid bar will be satisfactory. However, should failure occur from pure torsion the answer lies in increased diameter, whether tube or bar. For steels, the yield strength in torsion is directly proportional to the yield in tension.

(e) Impact. The merit of impact testing is still a controversial subject. Perhaps the *method* of testing is not indicative, but certainly impact is the cause for a large percentage of failures. Combined with a notch effect the results are decisive. For severe impact applications the parts should be heat treated. In every instance be sure there are generous fillets at section changes, a smooth surface finish, and freedom from tool marks.

(f) Fatigue. Fatigue or endurance limit may be defined as the load carrying ability for

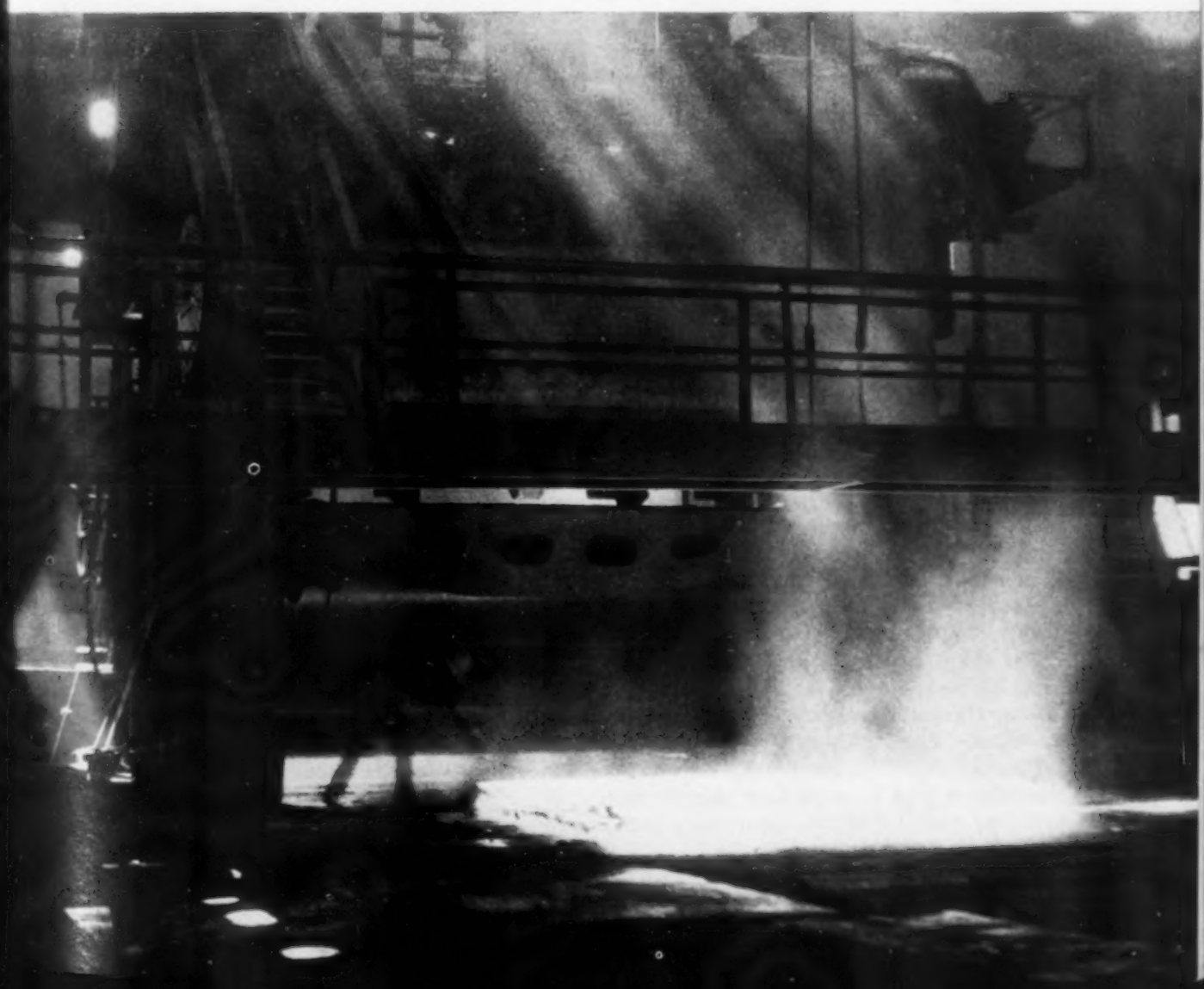
epeated applications of the load, whereas tensile trength is the load carrying ability for a single pplication. In the ordinary steels, not heat reated, there is a close relationship between ensile strength and the endurance of a smoothly olished test bar. When subject to a notch effect is advisable to limit the carbon content in the teel to 0.40% max., since the lower carbons have reater ability to cold work, which increases the trength at the notch, and materially increases he endurance limit.

The strength of the *outside* fibers of the bar s most important. As an example, if the decarurized surface is allowed to remain on the bar r part, the endurance limit is effectively that of he decarburized material, or about 30,000 psi., nstead of the endurance of the underlying steel.

Elements of design, such as sharp corners, nsufficient radius of fillets if any, sloppy workmanship in finishing such as a roughened achine finish and deep tool marks, V-threads articularly when torn or rough, and other irregularities which serve as stress raisers, are responsible for a large share of fatigue failures. Seldom are such failures the result of inclusions or other defects of the steel. J. O. Almen of General Motors Research Laboratories is responsible for the estimate that "fully 90% of all fatigue failures occurring in service or during laboratory and road tests are traceable to design and production defects and only the remaining 10% are primarily the responsibility of the metallurgist as defects in material, material specification or heat treatment." You will note that Mr. Almen exonerates the metallurgist *only in so far as material and heat treatment are concerned.* The metallurgist is not relieved of the responsibility of forcing through design or fabricating changes that will eliminate failures; he cannot wash his hands of the affair, because he is the one who knows the causes and effects of stress raisers; his is the responsibility in the end.

In regard to finishes and their effect on fatigue strength — it has been determined that

A Plate Mill That Really Rolls Them Big
Photo by Rittase at Lukens Steel Co., Coatesville, Pa.



fatigue failures result only from tension stresses, never from compression stresses. This is an important fact. Also, remember that most machining and grinding, particularly in the rough finishes, leave tension stresses in the outer fibers.

(Perhaps too much space has now been given to this topic, since the grade of steel selected has less to do with fatigue failures than have the mechanics of fabricating and the design. However, the trend toward increased operating speeds and lighter weight equipment has materially increased the percentage of failures through fatigue, and engineers of every category must now become cognizant of its causes and cures.)

my opinion, the cold bend test is the most feasible method of determining ductility, as a property of use to the designer and fabricator.

Another major consideration of steel selection is *toughness*. This is an arbitrary term and is usually settled by an arbitrary test. Properly defined, toughness is the energy required to cause rupture. In most instances the elongation and reduction of area obtained from the tensile test are improperly used as the measuring stick for toughness, whereas impact tests are the best laboratory test method for determining toughness. As a matter of fact it seems that simple practical tests on completed parts may prove

155-Mm. Gun of 1918 Design, With Riveted Carriage, Attached to 1941 Prime Mover; As Good a Gun as There Was, in its Day

(g) Creep. Slow deformation under continuous loading, or creep, is normally of concern in applications involving temperatures in excess of 600° F. Some creep or relaxation occurs in bolts tightened under high pressures, and particularly when subjected to intermittent loading.

Ductility, Toughness and Brittleness

Ductility is difficult to define since it has so many meanings. Sheet steel must be "ductile" enough to draw to the proper size and shape. Billets must have sufficient "hot ductility" to be forged. Wire must be ductile in order to be drawn through dies. Steels must be "ductile" rather than "brittle" for service applications. A common means of estimating ductility is by noting the elongation and reduction of area obtained by tensile tests. In many applications these values are of little importance. A correction for the misuse and looseness of this term lies in practical tests for the particular application. In

even more indicative for any specific application.

Brittleness is the opposite of toughness. If you can measure the one, you have measured the other. Both are a matter of degree. Designers, fabricators, and heat treaters must be fully aware of the importance of generous fillets, poor surface finish and similar notch effects. Otherwise a perfectly sound and satisfactory material may fail through *apparent* "brittleness".

Grain Size — The grain size, as rolled, is of importance to machinability, cold upsetting, and other methods of cold forming. The austenitic grain size is important in heat treatment and when parts are fabricated by welding, brazing, forging, and similar methods involving temperatures above the critical.

Wear and Corrosion Resistance

Wear resistance is primarily a function of composition and structure. Free carbides in a matrix of pearlite provide the maximum wearing

properties in untreated steels. For the average wear conditions involved in the use of parts made from untreated steels, cold drawn medium carbon steels are normally sufficient. Within the same basic grade of steel, except when in the spheroidized annealed condition, hardness values are an indication of wear resistance. When comparing different grades, remember that hardness is not necessarily a straight line function of wear resistance.

Essentially every problem in corrosion is a distinct and separate problem in itself. For severe corrosive conditions, a stainless steel or rustless iron should be used. There are intermediate products, of course, for less severe conditions. Low copper steels have been used extensively for atmospheric resistance, and ingot irons have been used with success in underground installations as culverts. Then there are many good surface treatments for corrosion prevention.

Corrosion materially reduces the endurance limit of a bare part, and too little consideration has been given to the corrosion fatigue of ferrous materials. Its importance is apparent when one remembers the obvious fact that corrosion roughens the surface, even deeply pits it at times, and these "stress raisers" are the loci of stresses far beyond the endurance limit of the material, even though the expected average of recurring stress at the surface is far lower.

Modern 155-Mm. Gun (M-1), a Bigger and Better Gun and Mount; the Welded Structure, Using High Strength Plate, Cuts Weight by 20%

Reliability and Workability

Reliability. The best method of insuring delivery of steel of uniform and reliable characteristics is to purchase from a reliable source. Educate your sources as to the fabricating and service requirements of the material. Let them serve as a partner to this extent. Remember, an established and reliable source of supply is of more value to the consumer than is the customer's business to the source.

Workability. Under this heading are classified forming methods such as welding, forging, machining, bending, and many other types of fabricating. Steel must have adequate physical properties, but of equal importance in competitive manufacturing is the ability to fabricate at minimum cost. This factor in steel selection deserves considerable emphasis.

General Summary of Factors

For a given application, the consideration of the above selection factors will usually indicate the characteristics of the steel that is required. It is then only necessary to select a steel having those characteristics. This makes it sound easy!

An important advancement in design and materials engineering is being made through stress analysis. The aircraft industry has pioneered this work and found it extremely advantageous. A better understanding of the stresses involved in a given application permits the designer and metallurgist to work more precisely. In addition — once the stresses are really known, relatively simple but adequate acceptance tests for production material may be developed; emphasis can be placed on practical testing, simulating conditions occurring in service operations. Herzig, in the January 4, 1943 issue of *Steel*, effectively summarizes the principles of testing as follows: "In the past a great deal of emphasis

has been placed on physical tests which are faithfully performed because we knew so well how to perform them, rather than because those tests precisely described the fitness of material for service. The new viewpoint focuses attention on fundamental characteristics, and not tests whose relation to performance is obscure at best."

Further comment on the meaning of tests seems unnecessary.

Selection of Plate

To many of us, plates have been of little concern. However, they are an *essential* commodity, and it is probable that even small-parts makers may find them useful and economical as a raw material for future production.

That the war effort depends upon the ability of the steel industry to produce plate has been adequately demonstrated. During the construction phase of this war, when army centers were being built and industry converted, the principal uses were for pressure vessels in chemical, munition, oil and rubber plants, boilers and power plant equipment, oil tanks, and pipe lines. As facilities became available, and the production of the implements of war attained its present scale, the use of plates shifted to bombs, tanks, ships and marine boilers. With these changing requirements the choice of the grade of plate has undergone even more radical change, yet the basic principles of steel selection have operated throughout. Each application has been compounded from the factors of design, mill fabrication, and shop fabrication.

Design factors include the volume of the vessel, its working pressure and temperature, and the nature of the product to be handled. The influence of pressure on containers such as cylinders and spheres has been the subject of mathematical studies supplemented by extensive testing. The tensile strength of the material has been correlated to its behavior in this design, and a wall thickness capable of withstanding the peak pressure can be selected. Operations at atmospheric temperature are well understood.

As the temperature requirements of the process go up, the physical properties of the steel change markedly. Thus the short-time tensile strength of carbon steel will change from 55,000 psi. at room temperatures, to 13,000 at 950° F. An increase in wall thicknesses would be necessary to meet such a condition. In addition, at temperatures above 700° F. steel will "creep", that is, appears to become plastic, and "gives" slowly with the stress. At more elevated temperatures, this will lead to structural failures in measurable time.

The nature of the product and the temperature used in processing regulate the degree of corrosion and thus the suitability of the various grades or alloys for that particular application. Consideration must also be given to the possibility of contaminating the product through corrosive reactions.

In the actual forming of the plate into a cylinder, and flanging and dishing the necessary heads, the steel undergoes permanent deformation. It is therefore essential that the plate possess the needed ductility, either in the hot or

Table I — Common High Tensile Steels

Name	Chemical Composition						Tensile Properties, 1-In. Plate, As Rolled		
	Carbon	Manganese	Silicon	Copper	Nickel	Other Elements *(a)*	Yield Point	Tensile Strength	Elongation in 2 In.
S.A.E. 1335 *(b)*	0.33	1.63	0.18	....	....	...	58,600	101,600	19.5 in 8 in.
2 to 2.5% Ni	0.35 max.	1.00 max.	....	....	2.00 min.	. ..	65,000	100,000	30.0
NE 9400	....	0.80/1.10	0.20/0.35	....	0.30/0.60	0.30/0.50 Cr, 0.08/0.15 Mo	60,000	90,000	10 to 20
Mn-V	0.13/0.18	1.20/1.45	0.15/0.30	....	....	0.10 V	55,000	80 to 95,000	18.0
C-Mo	0.13/0.25	0.50/0.90	0.15/0.30	....	....	0.50 Mo	42 to 57,000	72 to 79,000	27 to 20.6
Mn-Mo	0.15/0.30	1.20/1.75	0.20/0.50	....	....	0.35 Mo	50 to 80,000	75 to 120,000	....
S.A.E. X-4130	0.25/0.32	0.40/0.60	0.15/0.30	....	....	0.20 Mo, 0.90 Cr	70,000	90,000	20 to 10
Cor-Ten	0.12 max.	0.10/0.50	0.25/1.00	0.30/0.50	0.55 max.	0.50/1.50 Cr, 0.15 P	50,000	70,000	22.0
Man-Ten	0.30 max.	1.10/1.60	0.30 max.	0.20 min.	....	....	50,000	75,000	20.0
Yoloy	0.05/0.35	0.30/1.00	0.20 max.	0.85/1.10	1.50/2.00	....	53 to 85,000	68 to 105,000	....
R.D.S. 1	0.12 max.	0.50/1.00	....	0.50/1.50	0.50/1.25	0.10 min. Mo	55,000	70,000	25.0
R.D.S. 1A	0.30 max.	0.50/1.00	....	0.50/1.50	0.50/1.25	0.10 min. Mo	70,000	90,000	15.0
Hi-Steel	0.12 max.	0.50/0.70	0.30 max.	0.90/1.25	0.45/0.65	0.12 P	55,000	70,000	20.0 min.
Armco high tensile	0.12 max.	0.20 min.	0.10 max.	0.35 min.	0.50 min.	0.05 min. Mo	50,000	65 to 75,000	25.0 to 28.0
Jal-Ten	0.35 max.	1.25/1.75	0.30 max.	0.40 max.	....	....	50,000	80,000	20.0
Mayari R	0.12 max.	0.50/1.00	0.05/0.50	0.50/0.70	0.25/0.75	0.20/1.00 Cr, 0.10 P	50,000	70,000	22.0
A.W. Dyn-El	0.11/0.14	0.50/0.80	....	0.30/0.50	....	0.08 P	52 to 60,000	68 to 78,000	25.0
N-A-X high tensile	0.10/0.18	0.60/0.75	0.65/0.90	0.25 max.	0.10/0.25	0.15 max. Mo, 0.12 Zr, 0.60 Cr	50 to 65,000	70 to 85,000	32.0 to 50.0
Otiscoloy	0.12 max.	1.00/1.35	0.10 max.	0.50 max.	0.10 max.	0.10 max. Cr, 0.12 P	50 to 70,000	70 to 85,000	33.0 to 44.0
Lukens Cr-Mn	0.35/0.45	0.80/1.00	0.15/0.40	....	....	0.40 Cr	55% of t.s.	90,000	18.0

(a) Average, unless otherwise noted.
(b) Average of 168 heats of structural plate and shapes for Kill van Kull arch bridge.

cold condition. The use of welding as a joining method has been firmly established in all modern plate fabricating shops, yet it must be recognized that this introduces further limitations. Not all steels can be welded without damage, and considerable precaution must be used on a great many others. In general, carbon steels containing about 0.30% carbon and more offer serious welding problems; the danger of cracking is always present. This is aggravated in the use of low alloy steels, therefore in them the carbon is usually reduced to 0.20%. Secondly, the heat generated by welding may reduce the physical and corrosion properties of the base metal adjacent to, or in the weld; this further complicates the design and choice of correct thickness. Finally, additional fabricating facilities such as large stress relieving furnaces and radiographic equipment may be required.

Riveted structures may avoid some of the above problems, but joint efficiencies are further reduced. In addition, modern equipment and processes in the chemical industry and in the central station steam plants have tended toward higher pressures and temperatures, necessitating wall thicknesses far beyond the range of riveting, as shown in the view on the next page. Hitherto, huge hollow bored forgings represented the sole solution, but advanced welding technique has afforded a more economical alternative.

The maximum dimensions in plate sizes depend upon the particular steel mill. For widths up to 160 in. there are several mills available. For the extreme design cases it is possible at one mill to roll widths up to 206 in. (page 707).

At this point it is proper to mention the *cost* factor. Normally, there will be a choice of steel analyses, sizes, and mill treatments. All other factors being equal, the type and size of plate to be ordered should represent the lowest costs in the overall sense. For example, at times it is desirable to pay mill extras for additional width and length to eliminate joints, for which the cost of welding and inspection is high.

The American Society for Testing Materials' carbon steel plate specifications will cover the majority of applications. A summary of these is given in Table II. Compared with the S.A.E. specifications for alloy steel, the chemical requirements are quite "sketchy", more dependence being put on physical properties in the metal as delivered from the mill to the fabricator.

High Tensile Plate

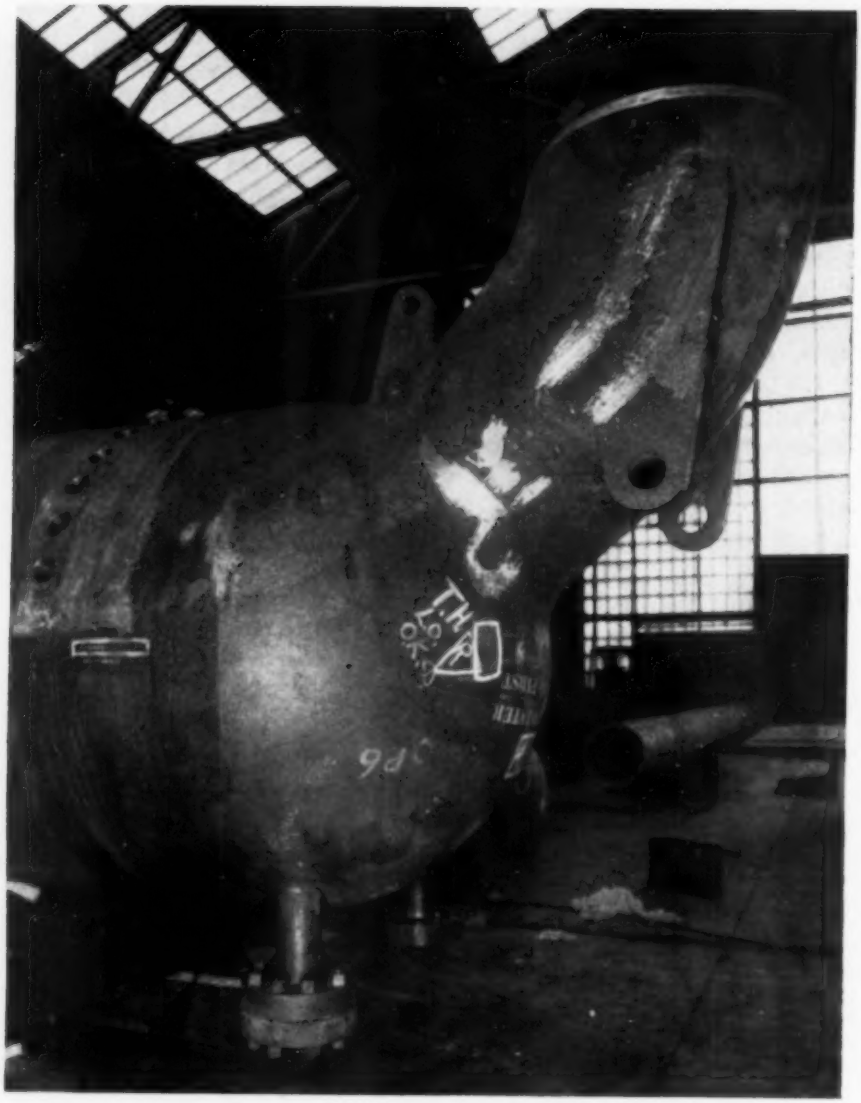
A new class of applications is becoming more prevalent wherein the weight is important. The need for high strength steels, some with better corrosion resistance, to substitute for the lower strength carbon steels has long been recognized by the railroad industry. Considerable impetus to this movement has been given by the low alloy, high tensile plates. These are generally of a proprietary composition and usually sold by trade name to minimum physical properties. Some of the more common ones are listed in Table I, page 710. Some compositions are such that they are technically alloy steels, while others conform to the commercial definition of carbon steels. For some time now the production of some of the more highly alloyed steels in this category has not been authorized for private account; however we all hope this limitation will not exist for a much longer time.

While the transportation industry's equipment, including railroad cars, trucks, buses, and street

Table II — Summary of A.S.T.M. Plate Specifications

Specification	Physical *(a)*	Chemical Limitations *(b)*		
	Tensile Strength (1000 Psi.)	Maximum Carbon *(c)*	Maximum Manganese	Other Limitations
	Structural Steels			
A7 — Bridges, building	60 to 72	....	....	0.20 Cu min. (if specified)
A8 — Structural nickel	90 to 115	0.43	0.80	3 to 4% Ni, 0.20 Cu
A94 — Structural silicon	80 to 95	0.40	....	0.20 Si
A10 — Mild steel	55 to 65	....	....	0.20 Cu min. (if specified)
A78 — Welding quality A	45 min.	0.17	0.35 to 0.80	0.06 max. P
A78 — Welding quality B	50 min.	0.22	0.35 to 0.80	0.06 max. P
A113 — Railroad cars	50 to 65	....	....	0.20 Cu min. (if specified)
A113 — Locomotive structural	55 to 65	....	....	0.20 Cu min. (if specified)
A113 — Cold pressing	48 to 58	....	....	0.20 Cu min. (if specified)
	Boiler Steels *(d)*			
A30 — Boiler flange	55 to 65	....	0.30 to 0.60	2 in. thick
A30 — Boiler firebox A	52 to 62	0.25	0.30 to 0.60	0.25 Cu (max.), 2 in. thick
A30 — Boiler firebox B	48 to 58	0.25	0.30 to 0.60	0.25 Cu (max.), 2 in. thick
A70 — Boiler flange	55 to 65	....	0.80	2 in. thick
A70 — Boiler firebox	55 to 65	0.25	0.80	4 in. thick
A89 — Low tensile flange A	45 min.	0.15	0.35 to 0.60	
A89 — Low tensile firebox A	45 min.	0.15	0.35 to 0.60	
A201 — Carbon silicon A	55 to 65	0.20	0.80	0.15 to 0.30 Si
A201 — Carbon silicon B	60 to 70	0.24	0.80	0.15 to 0.30 Si
A212 — High tensile A (flange)	65 to 77	0.28	0.90	0.15 to 0.30 Si, 2 in. thick
A212 — High tensile B (firebox)	70 to 82	0.31	0.90	0.15 to 0.30 Si, 4½ in. thick

(a) Yield strength (min.) equals ½ tensile strength (usually with certain deductions for thick plates). Min. elongation in 8 in. for flange steels usually equals 1,500,000 ÷ tensile strength; bending tests are also required.
(b) P, 0.04% max.; S, 0.05% max.
(c) Carbon limits frequently vary with thickness of plate.
(d) All boiler steels require a homogeneity test.



Boiler Drum and Domed Head, Completely Welded From 6¾-In. Steel Plate (70,000 Psi.). Vertical goose neck welded of 3¾-in. plate. Unit withstands 2500-psi. pressure. Courtesy Babcock & Wilcox Co.

cars, has received most of the tonnage produced in low alloy, high tensile plate, other imortant applications have been for construction equipment, such as for cranes and earth movers. Redesign of booms, using low alloy, high tensile steel, and welded joints have decreased the weight almost 30%. Much is now being used for war materiel; some for mechanical parts.

Fabricated assemblies have replaced castings in industrial equipment such as water wheels, blowers, and cyclone scrubbers. The weight saved through a combination of high strength and welding technique increases the machines' efficiency. Reduction of dead weight in static structures — such as bridges, structural frames, and supports — has led to overall reduction of costs in the complete structure. A promising field exists in the more general use of this material, when it becomes available.

Care must be exercised in replacing cast iron with steel in some applications. Thus, in the redesign of machine tools, such as planer and lathe beds, it was found in some instances that high tensile steel could not be utilized to save weight because of its unsatisfactory "damping capacity". In operating such a light-weight machine tool, excessive vibration was set up in the frame when heavy cuts were taken, with the resultant poor finish and high machine tool depreciation.

One of the main considerations in the design of mobile gun mounts and carriages is the overall weight. An outstanding Ordnance development since the last war is the substitution of low alloy, high tensile welded gun trails for riveted carbon steel trails. The mobility and tactical characteristics of the weapons were materially increased by a weight reduction, running up to 20%. Decreased fabricating costs and greater production, also achieved, are of no small importance. A good example is given in the photographs on pages 708 and 709.

Another important field of application of high tensile plates lies in the fabrication of small parts such as gears, cams, sprockets, and similar shapes, utilizing flame cutting and blanking processes, both of which have been developed to a high degree of accuracy. It has frequently been possible to flame cut and flame harden parts more economically than by casting or forging, followed by machining and heat treating, where dimensional tolerances will permit.

The extended use of plate is very closely connected with the growth of welding as a method of shop fabricating. The use of welding rod itself has increased from 18,000,000 lb. per month in 1940, to over 80,000,000 lb. per month in 1943.

Bits and Pieces

Metallurgicus's

Own Department

Metallurgicus reappears in this issue, after an unavoidable and regrettable absence, and discourses on so practical a subject as adjusting the temperature of the quench to the part being quenched, and keeping that temperature constant. Most of his friends know that publishable items in this department rate any of the ⊜ books (except the Handbook).

Controlling the Temperature of Quenching Oil

IN A SERIES of short discussions in these columns a few months ago, some of the fundamentals of good oil quenching were brought out, principally with respect to *getting the oil to the work* so it can do its required job of taking away heat quickly and uniformly.

Another essential factor for good and consistent results is maintenance of reasonably constant oil temperature. (Of course, the following remarks apply equally well to aqueous solutions such as brine or sodium hydroxide.) The heat-extracting power of oil varies greatly with its temperature, and temperature for maximum quenching effect is by no means the same for different oils. This point was thoroughly brought out in an excellent paper by Spring, Lansdale and Alexander given at the 1943 convention and printed in Vol. 33 of *Transactions* ⊜, page 42. It will repay an evening's reading (or re-reading); the amount of discussion which this paper evoked is an indication of the commercial and practical importance of the subject treated, namely "An Evaluation of Quenching Oils".

It is ordinarily desirable to use the oil, regardless of type, at the temperature which gives fastest cooling. (My research friends might wish to rephrase the last part of the sentence, "at the temperature which cools the steel from quenching temperature past the nose of the S-curve — where transformation starts with the least delay — in the shortest time".) It is also essential for uniformity of hardening and control of distortion that the oil temperature be held within reasonable limits — say 30°, although narrower or wider limits may sometimes be useful. This means that the oil must be heated if too cold (which only occurs at the beginning of a work period) and, always, cooled to remove heat added by the quenched steel.

The necessity for heating cold oil to the proper operating temperature is sometimes overlooked with disastrous consequences. A simple steam coil in the tank will take care of this; more elaborate arrangements may be made, of course, such as a system of automatic valves admitting either steam or cold water to the heat exchanger (oil cooler) as required.

Cooling of the quenching oil is practically always necessary unless only small amounts of work are quenched in large tanks. Good agitation of the oil will go a long way toward eliminating localized overheating of the oil — in fact, the local heating is a big reason for the need of good agitation. But some means must be provided for taking away from the oil the heat it takes from the hot steel. There are several ways this can be done. "Cooling" the tank by surrounding it with a water jacket is very unsatisfactory, for obvious reasons.

If the oil is pump-circulated (as for pressure-quenching or some of the other methods discussed in earlier issues) it is quite easy to hook in a heat exchanger of some type. The simplest is built like a copper-coil domestic hot water heater, with oil flowing around the outside of the coils and cold water (or steam, as mentioned above) through the tubes. Larger, more elaborate devices are available for large systems, and the cooling water cost may be reduced by evaporator-

coolers so the water may be re-used. Another variation consists of a concentric pipe cooler, looking like a large steam radiator, water running through the central pipe and oil through the annulus between central and outer pipe (or vice versa). This arrangement has a lot of joints and hence many places where leakage can occur, with resultant spoiling of the oil. Welded construction will help, if proper allowance is made for differential expansion of pipe at different temperatures.

A very ingenious scheme has been occasionally used employing one or more auto or truck radiators in tiers, with the oil trickling over them while water is circulated through the insides in series; this is very compact and effective, although subject to the hazard of leakage.

For individual quench tanks — particularly if remote from the regular oil system (or where there is none) and when pump circulation is not required — one of the best methods of cooling consists of a copper coil immersed in the tank at one end, through which the water is circulated; a motor driven propeller at the bottom of the coil insures quick heat transfer while also imparting good agitation to the oil for quenching. I have never seen this gadget advertised. An outboard motor could easily be adapted. A standard paint mixer, with the addition of a copper coil, I have discovered, is particularly effective for use in tool-hardening tanks.

Cooling of quenching oil is a real problem, and deserves constant attention. Money spent on thermostatic valves is well spent, and study of best temperature for oil may indicate some possible further economies. Obviously, 100° F. is easier to maintain than 80°, and 150° easier (in a large, busy heat treat) than 100°. The usual cheap, effective "light mineral oil" seems to work best at 100 to 130° F. A few years ago one of the leading gear producers was experimenting with an oil temperature of 260° F. for quenching carburized gears, and appeared to be getting splendid results. Can any readers of "Bits & Pieces" add any later information on this?

METALLURGICUS.

Spotting Cobalt High Speed

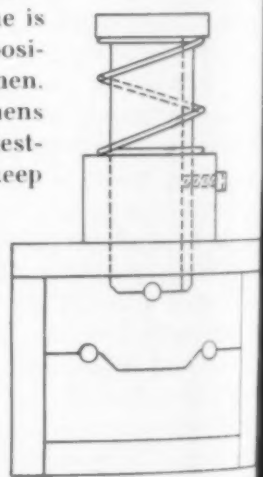
ONE OR TWO useful ideas may be added to the schemes already noted in "Bits and Pieces" for distinguishing tungsten high speed toolsteel from the varieties containing cobalt. I can testify to their reliability, for they have been used since 1911, when Supt. Kowallik of Becker Steel Works in Germany transmitted his new formula for cobalt high speed to the English firm with which I was then associated.

George Roberts (in May *Metal Progress*) uses a drop of concentrated hydrochloric acid; within 30 sec. a bluish color will appear around the edges. A clean surface (a ground spot) helps considerably; also the reaction is faster and clearer if the steel is warm to the touch.

Robert Gross in the August issue recommends the application of filter paper dipped in the acid. Here again a clean surface is desirable — even if not absolutely necessary. A few vigorous strokes with emery paper will help; a spot grinder is even better. (VICTOR F. J. TLACH, Latrobe Electric Steel Co.)

Bend Tests Above Room Temperature

FINDING IT NECESSARY to make bend tests above room temperature, we made a fixture as shown in the sketch. The anvil slides out so that it can be placed in the same furnace with the bend specimens and replaced just before the test is made. The fixture is also warmed, and the anvil is a snug fit so that alignment is maintained and no time is wasted in the proper positioning of the test specimen.



Bending Fixture With Movable Anvil, Preheated to Testing Temperature

To carry the specimens from the furnace to the testing machine and still keep them hot, we took a piece of cold rolled steel and drilled a hole in it deep enough so the specimens would be completely surrounded when dropped in. A handle was fastened to the carrier as a further convenience; we also heat this carrier with the bend specimens.

By thus keeping the bend specimens at the proper temperature until the test actually starts, having the fixture warm, and making the test on a hot anvil, the temperature *at the time of testing* could be relied upon, at least close enough for our purposes. Any closer control would probably require us to build a furnace around the testing fixture — an awkward alternative if a large number of tests are to be made. Our specimens (0.187 in. square) will still be over 200° F. after 1 min., when the starting temperature is 300° F. (C. F. SAWYER, Carnegie Institute of Technology)

Salt Baths for Copper Brazing

THE ILLUSTRATION shows a small gun assembly that was giving a good deal of trouble, producing 15% rejects, until the work was transferred to our salt bath line-up for high speed steels. The operation consists of copper brazing two small cheek plates of S.A.E.1030 near the end of a bar of 1050 steel. The plates, approximately 1 sq.in. area and ⅛ in. thick, are first tack welded (by spot welder) to the sides of the strip, a copper shim being inserted prior to welding. The parts are then placed in a rack which holds 20 pieces, and are ready for brazing. Bar ends are first immersed in preheat bath at 1550° F., then transferred to the high heat bath at 2090° F. and held 45 sec. (measured by time clock and warning light). The parts are then transferred to the third salt bath in line, the one ordinarily used for quenching high speed tools.

The salt quench is one of the reasons for the outstanding success of the entire process. This salt quench checks the flow of copper immediately, eliminating any tendency to run or blow or form a blob on the surface of the work. The work comes clean and smooth excepting for a thin coating of salt. Temperature, usually held at 1150° F., is not critical; it is only necessary

that the quench be salt, since a water or oil quench will invariably blow the copper out.

After the quench, the work is water hardened and straightened. This is also a simple matter since the use of the salt bath prevented any noticeable decarburization that is usually present with conventional methods of brazing in a reducing atmosphere. The work is merely reheated to 1550° F. in the "preheat" salt immediately after the salt quench, and then cooled in water so that the end of the bar is hardened to the required C-50 to 52 Rockwell.

An interesting feature of the process is that flux is not required; the salt itself acts as a flux. Production in this line-up of Upton electric salt bath furnaces with automatic heat control, and without elaborate conveyors, is 600 parts per hr. (CHARLES R. ST. JOHN, Proprietor, Industrial Steel Treating Co.)

Removing Broken Tools From Aluminum Alloy Parts

BROKEN TAPS, drills and reamers have caused many an expensive casting or forging to go to the scrap pile. The normal method of tackling such problems (dependent of course on the shape of the part and the position of the snapped-off tool) is by gouging round the broken section and levering or pulling it out, by drilling and reaming a hole from the opposite side of the part in line with the original hole and then knocking the section out, or by other laborious and time devouring operations. The devastated hole from which the broken tool has been removed has now to be plugged with aluminum and sometimes requires welding.

This serious problem has been overcome by an electrolytic process which dissolves out the broken tool in a remarkably short time without detrimental effects to the part. The process consists of suspending the part in a steel tank (size to suit dimensions of part) with an electrolyte composed of a saturated solution of ammonium sulphate (750 g. per liter) and having a voltage varying between 25 and 50. The current is not important except that the higher the amperage the faster the steel tool will dissolve, the maximum current being restricted by the fact that if the current is too high, the protective coating formed on the aluminum alloy will be broken down and the part will be severely attacked. The part containing the broken tool is the anode, and it must be immersed in the solution although the remainder of the part does not necessarily require to be. The cathode is comprised of steel plates. After the tool has been dissolved or loosened, the part is removed from the bath, carefully washed and dried.

During the electrolysis very little aluminum is removed, even though aluminum is above iron in the electrochemical series, owing to the speedy build-up of a protective oxide coating.

Using an initial voltage of 25 volts and a current of 50 amperes a broken tap was almost completely dissolved in approximately two hours. It is not essential for the broken section to be dissolved completely, it being sufficient for the section to be loosened in the hole enough to allow it to fall out with gentle tapping.

Two precautions: First, there should be no other metal section on the part other than the broken tool, otherwise it also will be attacked and dissolved. Second, the parts should be sound, or the porous areas will be severely attacked. (C. A. E. WILKINS, Metallurgist, Albion Motors, Ltd., Glasgow)

Emery Graves Gilson Pi

American;

Scientist; Researcher;

Metal Progress; Page 716

Pioneer in Powder Metallurgy

October 1, 1944

At this festive occasion, your 75th birthday Mr. Gilson, we trust that you will at last permit us to say a little about your life. . . . .You were born in Machias, Maine; were graduated in engineering from Cornell where you were a member of the varsity crew for three years; you served in electrical engineering and administrative posts for eight years thereafter; you married Mary Fitzsimons of Waterbury, Conn., and have two grown sons — one in the Army, the other in defense work; you spent 32 years in the General Electric Co.'s Research Laboratory in Schenectady and the last ten as a consultant in powder metallurgy. This is but an outline of the honorable record. From your colleagues, your notebooks, and the patents that the General Electric Co. asked you to write, we also learn that you were intimately connected with the development of fused quartz, metallized carbon filaments, tungsten metallurgy, lightning arresters, bearings and their lubrication, high-tension underground cables, tungsten carbide, electrical contacts, and precision casting. You developed the metal-graphite brush for generators and motors in 1908, and from this originated the metal powder product known as "Genelite" used for bearing and anti-friction applications. You are still active in the field of powder metallurgy and are now doing research work on the friction of rubbing surfaces — still a true mystery. Others have published much and received acclaim here and abroad, you held onto that heritage of the country and seafaring men of the easterly counties of Maine who abhor tall talk and long writing; nevertheless you were always a cooperative member of the team. In Patent No. 1,177,407, which establishes you as the inventor of the so-called oil-less bearing, one might object to your literary parsimony until he follows the teachings of the patent; then he will recognize the basic techniques and physico-chemical fundamentals inherent in your frugal statements. In spite of your reticence, we know that should we be stranded on the road from Schenectady to Troy, there is a lovely farmhouse on the hill where we can get old fashioned New England hospitality and good conversation about fast sailing and old-time fishing in Machias Bay. When you take the garrulous wanderer to the crest of the hill to view the Berkshires, the Green Mountains, and the White Mountains to the East, the Adirondacks to the North, and the Catskills and the Helderberg to the South, he also becomes silent.

A toast, gentlemen! To Emery Graves Gilson, American, Investigator, Metallurgist, Friend, whose 75th birthday is today!

John Wulff

Recent Improvements in Lead Alloy Coatings for Steel

By C. H. Hack,
D. S. Kondrat
and H. E. Zahn
National Lead Co. Research Laboratories,
Brooklyn, New York

War-time shortages in tin and zinc — the two most used protective coatings on steel — and a relative abundance of lead caused a quick conversion of many hot dip operations to the use of a lead alloy much lower in tin than the conventional terne-plate coating. The authors studied the details of the process — principally the formulation of a suitable flux, and a corrosion resistant lead containing the minimum of alloying constituents for successful bonding to the steel. Results have been so satisfactory from a fabrication, performance and cost standpoint that a wide post-war use may be predicted.

THE INCREASING USE of and interest in tin-lead alloy coatings on steel is indicative of the general acceptance of a new coating alloy, low in strategic tin. Firm adherence of coatings, superior performance in forming and drawing operations, suitability for painting without special preparation, and excellent corrosion resistance are properties which individually and collectively attract new and wider fields of use.

The possibility of making deep draws with the lead alloy coating acting as a lubricant, and of forming coated sheet without fracturing or breaking the continuity of the coating, appeals to the fabricator.

The ability of lead and lead alloys to resist atmospheric corrosion has been known and utilized for many centuries. The lead roofs of the old cathedrals of Europe have withstood hundreds of years of varying climatic conditions. In general, the addition of small percentages of antimony and tin improves the atmospheric corrosion resistance of the lead, but the unusual protective value to steel of lead coatings, containing less than 3% tin, was discovered only within the past few years. Fluxes also have been developed that insure excellent adherence and coverage by these low tin alloys. It is now possible to produce thoroughly satisfactory coatings of this alloy at a reasonably low operating temperature.

Lead, like certain other common metals, is able to resist atmospheric corrosion because of the formation of a firmly adhering, practically insoluble, protective film. The permanence of these protective films is dependent upon the bond between the film and the metal, as well as upon the insolubility, impermeability and self healing property of the film. A few of the common metals showing the well-known ability to resist corrosion in normal atmospheres by this mechanism are lead, copper and aluminum, and many of their alloys.

Resistance of lead and other metals to various atmospheric environments is shown in the various reports to the American Society for Testing Materials by Committee B-3 on the Corrosion of Non-Ferrous Metals and Alloys. The report

Table I — Calculated Average Penetration (Inches x 10^{-4}) After 10 Years' Exposure

Commercial Metal	Industrial or Semi-Industrial		Sea Coast		Rural	
	Altoona, Pa.	New York, N. Y.	Key West Fla.	La Jolla Cal.	State Col. Pa.	Phoenix Ariz.
Chemical lead	2.7	1.7	2.2	1.6	1.9	1.0
1% Antimonial lead	2.1	1.2	2.1	2.4	1.3	1.1
Prime western zinc (99%)	19.1	19.3	2.1	6.8	4.0	1.0
High grade zinc (99.9%)	19.3	20.2	1.8	6.3	3.4	0.7
Copper (tough pitch)	4.6	4.8	2.0	5.2	2.3	0.5

for 1943 (*Proceedings*, Vol. 43, p. 135) shows the weight loss of metal plates 9 by 12 by 0.035 in. after ten years' exposure at six locations in the United States. From these values, the average corrosion penetration in inches has been calculated in Table I for lead, 1% antimonial lead, zinc and copper. The results clearly show that in all atmospheres — industrial, semi-industrial, sea coast and rural — the extent of the corrosion of lead is extremely small, and this again proves quantitatively the effectiveness of lead and most of its alloys as protective coatings.

Bonding of Lead to Steel

Lead does not "alloy" with steel, in the usual sense of the term, and therefore its bonding thereto as a coating metal can be accomplished only under definitely controlled conditions. However, lead alloyed with certain other metals develops an excellent bond with steel. A typical example is terne plate, which is steel coated with an alloy of lead containing 15 to 25% tin, a metal that is outstanding in its ability to bond with steel. Moreover, the tin also increases the atmospheric corrosion resistance and hardness of the coating.

The advent of the war with its resultant increase of production created wide demands for corrosion protective products. Terne plate and galvanized iron not being available in quantities adequate to meet the needs, there was an immediate turn to substitutes or replacements. Since lead and its alloys were known to possess excellent corrosion resistant properties and since lead was readily available in sufficient quantities, it was logical for metallurgists to undertake further investigation of the value of lead alloys as protective coatings.

Bonding qualities had to be studied first, without the use of such large amounts of tin as are contained in terne plate. More efficient fluxes had to be perfected which would lend themselves to the increased production tempo. As far as bonding is concerned, it was found that lead alloys containing antimony and silver could run the tin as low as 2.5% without impairment of bonding or corrosion resistant characteristics. Likewise, non-aqueous fluxes were developed for these low tin alloys.

Table II — Outdoor Protection of Iron by Couple Action of Other Metals of Equal Area★

Test Site and Nature	Pb to Fe	Cu to Fe	Zn to Fe
La Jolla, Cal. (foggy-seacoast)	2.47/0.52 +	0.25/0.05 + ?	2.18/0.08 +
Sandy Hook, N. J. (smoky-seacoast)	1.78/0.45 +	1.92/0.95 +	2.60/1.62 + ?
Key West, Fla. (seacoast)	1.44/0.36 +	1.00/1.86 —	2.00/0.02 +
Pittsburgh, Pa. (industrial)	1.39/1.10 + ?	0.63/1.74 —	1.77/0.02 +
Altoona, Pa. (industrial)	1.42/1.01 +	0.43/1.38 —	1.26/0.45 +
Rochester, N. Y. (industrial)	1.43/1.38 + ??	0.48/1.46 —	0.30/0.04 + ?
New York, N. Y. (industrial-seacoast)	1.06/0.98 +	0.62/1.44 —	1.79/0.03 +
State College, Pa. (rural)	1.56/0.62 +	1.19/1.36 — ??	3.00/0.31 +
Phoenix, Ariz. (desert)	1.24/0.67 +	1.60/1.12 + ?	4.10/0.07 +

Note: The first figure of the ratio represents the weight loss of the metal when coupled with iron divided by the weight loss of the metal when coupled with itself. The second figure represents the weight loss of the iron when coupled with the metal in question divided by the weight loss of the iron when coupled with itself. Where the first figure is larger than 1.00 and the second figure smaller than 1.00, the metal in question is anodic to the iron and tends to protect it and the couple has been marked +. Where the reverse is true, the metal accelerates the corrosion of the iron and the couple is marked —. In some instances both figures are larger or both are smaller than 1.00. If in this case the first figure is substantially larger than the second, the couple has been marked + ?, and if the second is substantially larger than the first figure, the couple has been marked — ?. Where the differences are small two question marks are used.

★K. G. Soderberg, "Properties of Plated Lead Coatings on Steel", 1943 *Proceedings* A.S.T.M., Vol. 43, p. 562.

While all commercial metal coatings are more or less porous, evidence recently has been brought forward to show that a small degree of porosity in lead coatings is not detrimental to atmospheric exposure, as was previously supposed. While such coatings may rust a little at first, this rusting does not continue. A possible explanation of this is given by K. G. Soderberg, who refers to the work of the American Society for Testing Materials: "Corrosion of Non-Ferrous Metals and Alloys", giving the data in Table II.

Soderberg concludes that "lead coatings have a greater tendency to protect underlying iron electrochemically through pores in the coating in uncontaminated or sea coast atmospheres than in an average industrial atmosphere". T. H. Westby, senior testing engineer in the chemical division of Sears Roebuck & Co., also informs us that he has found no visible signs of failure of hot dipped lead alloy coated gutters and downspouts after two years' exposure to the industrial atmosphere of Chicago.

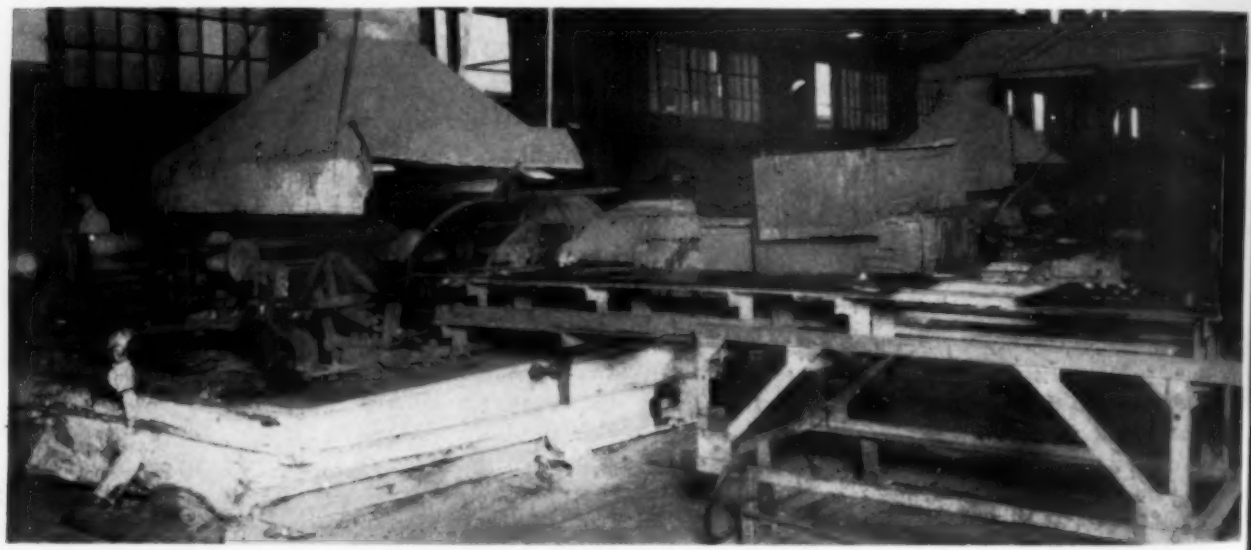


Fig. 1 — General View of Hot Dip Pot From Feeding Side. Courtesy Continental Steel Corp.

Method of Application

Coating steel with lead alloy by the hot dip process does not involve any radical changes in existing equipment such as shown in Fig. 1. A change in flux and slight changes in operating temperatures are the only departures required.

Commercial hot dip coating practices involve cleaning, pickling, fluxing, coating, quenching and finishing.

The cleaning operation is necessarily various. Some work, for example, requires sand blasting or shot blasting. Die cut parts and fabricated sheet steel units are often cleaned by vapor degreasing or alkaline solutions. Acid pickling may be used alone or in conjunction with a preliminary cleaning operation. The concentrations and temperatures of the various pickling baths are adjusted carefully, according to the amount and character of surface contamination to be removed and the particular type of work involved. Electrochemical cleaning is frequently employed as an adjunct to mechanical cleaning or ordinary pickling. All of these cleaning methods are so well known that they require no detailed description. Similarly, it is recognized that the base metal must be handled carefully at all stages of the cleaning operation to avoid any contamination. Iron compounds formed during pickling must be removed prior to dipping.

Fluxing is particularly important. It completes the cleaning and insures proper wetting of the base metal by the coating alloy. Special anhydrous fluxes have been formulated for the application of low tin-lead alloy coatings on cold rolled and hot rolled steel, malleable iron, brass, copper, copper alloys and other metals. Anhydrous flux of this type can have a melting point well below that of the alloy, and has a much lower specific gravity so it floats readily on the molten alloy bath. It is non-volatile and, furthermore, does not decompose upon continued heating.

The actual coating operation involves simply the immersion of the cleaned article in the flux bath and then in the coating alloy, with the usual agitation to free adhering flux. Very small parts are handled by means of baskets of suitable mesh. Parts are centrifuged and separated by a

(The article continues beyond the 4-page insert.)

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MAGNESIUM RICH BINARY ALLOYS*

Compiled by F.R. Morral

Group	Alloying Element	Atomic No.	Solubility at Eutectoid Temperature, %	Solubility at 20°C. or as Indicated	Eutectic		Second Constituent						Maximum Strength		Maximum Hardness		Effect of Alloying Element on		Solid Solution	
					Temperature, °C.	Composition, % of Alloy	Formula	Magnesium Content, %	Melting Point, °C.	Crystal Structure	Lattice Parameter, A.U.	Atoms in Unit Cell	Psi.	Composition, % Alloy	Brinell No.	Composition, % Alloy	Ductility	Resistance to Marine Atmosphere	Composition, % Alloy	Lattice Parameter
I A	H	1	0.0017 @ 650°C.	0.0036 @ 960																
	Li	3	5.7	5.7	582	7.3	Mg_9Li	82.5							52	2			5.7	3.185; 5.120; 1.607
	Na	11	Insoluble in solid and liquid states																	
	K	19	Insoluble in solid and liquid states																	
	Cs	55	Insoluble in liquid state																	
II A	Be	4		0.05 (?)	No alloys obtained								Down				Up	Up		
	Ca	20	1.8	0.18 @ 200	516	16.3	Mg_2Ca	54.82	714	Hexagonal	$\begin{cases} a = 5.288.1 \\ c/a = 3.464 \end{cases}$	8			60	1	Up	Up		
	Sr	38	0.15 @ 570°C.	0.11 @ 450	582	18.4	Mg_9Sr	71.41	606											
	Ba	56			618	13.8	Mg_9Ba (1)	61.44	704	?					45	0.2				
III A	La	57	?	?	571	14.7	Mg_9La (1)	61.18	662											
IV A	Zr	40	0.8 @ 700°C.	0.3 @ 300			Mg_2Zr						Up		42	0.5		Up		
	Th	90	Large (?)	Age Hardening (5)			Mg_2Th (?)	?					Up (33,000)	2			Up			
VI A	Cr	24	No alloys obtained															Down		
	W	74	No alloys obtained																	
VII A	Mn	25	2.1	0.2 @ 450	651		α-Mn						28,000 (7)	2	50	2.5	Up	Up	3.3	3.197; 5.195; 1.624
VIII	Fe	26	Insoluble in solid and liquid states															Down		
	Co	27			635	5 (?)	?								41	5		Down		
	Ni	28	0.1		507	23.1	Mg_2Ni (1)	45.32	762						41	0.1		Down		
	Pt	78					Mg_9Pt	19.92												
I B	Cu	29	0.03	0.02	482	30.7	Mg_2Cu	43.35	568	Hexagonal	$\begin{cases} a = 5.281 \\ c/a = 3.464 \end{cases}$	8			38	0.2		Down		
	Ag	47	1.6	0.09 @ 200	469	47.9	Mg_3Ag (1)	40.35	492	Hexagonal		8	Up		93	20	Up	Down	13.45	3.18426; 5.16169; 1.620
	Au	79	0.8	?	576	38	Mg_3Au	26.08	818											
II B	Zn	30	8.4	1.7 @ 200	340	53.5	$MgZn_2$ (1)	27.11	354	Hexagonal	$\begin{cases} a = 5.53 \\ b = 8.58 \end{cases}$		28,000	2	82	15	Down		8.0	3.189; 5.179; 1.6238
	Cd	48	Complete solid solubility										28,000	15	52	30	Up		47.2	3.16560; 5.13998; 1.631
	Hg	80		?	448	64.5	Mg_3Hg (1)	26.67	509	Hexagonal	$\begin{cases} a = 4.858 \\ c = 8.639 \end{cases}$	8								
III B	Al	13	12.6	2.3	436	32.2	Mg_4Al_3	54.59	463				38,000	? (7)	120	19	Down	Down	11.44	3.16282; 5.14717; 1.6714
	Ga	31	8.6	0.8 @ 200	423	40.4	Mg_5Ga_2	46.58	456	b.c.orthorhomb.	$\begin{cases} a = 15.72 \\ b = 9.0 \\ c = 8.02 \end{cases}$	8	Up				Up		6.9	3.19396; 5.18636; 1.6238
	In	49	53.4	42.8 @ 200	484	62	Mg_5In_2 (6)	44.63	?										38.35	3.18745; 5.20351; 1.6328
	Tl	81	60.5	39.8 @ 200	405	73.7	Mg_5Tl_2	22.93	413	b.c.orthorhomb.							Up		45.73	3.19456; 5.20521; 1.6294
IV B	C	6					Mg_2C_3 (2)													
	Si	14	0.004 @ 800°C.	?	637.6	1.4	Mg_2Si	63.4	1102	f.c.c. (CaF_2)	6.391	4	34,000 (8)	1	50	5.8		Down		
	Ge	32	0.1 @ 600°C.	0	634.7	3.4	Mg_2Ge	40.1	1115	f.c.c. (CaF_2)	6.378									
	Sn	50	14.8	2.3 @ 440	560.6	36.4	$Mg_{24}Sn_{12}$	29.07	778	f.c.c. (CaF_2)	6.765	4			70	25	Down	Down	11.0	3.20072; 5.20685; 1.6264
	Pb	82	39.6	0	465	68	Mg_2Pb	10.01	550	f.c.c. (CaF_2)	6.836		Up		52	30	Up	No Effect	38.06	3.20786; 5.23298; 1.6318
V B	N	7					Mg_3N_2	72.26		cubic	9.95									
	P	15					Mg_3P_2			cubic	12.33	16								
	As	33					Mg_3As_2	32.75	800	b.c.c.	12.33	80								
	Sb	51	?	?	630	35.7	α-Mg_3Sb (6)	23.05	1228	Trigonal-A (4)	$\begin{cases} a = 4.573 \\ c = 7.229 \end{cases}$				55	5	Down	Down		
	Bi	83	11.4	2 @ 325	551	59.0	α-Mg_3Bi_2	14.86	823	Trigonal-A (4)	$\begin{cases} a = 6.22 \\ c = 7.401 \end{cases}$				58	14		Down	9.05	3.20485; 5.20789; 1.6248
VI B	O	8					MgO	60.32	2800	f.c.c. (NaCl)	4.19									
	S	16					MgS	43.12	2000	f.c.c. (NaCl)	5.19									
	Se	34					$MgSe$ (7)	23.5		f.c.c. (NaCl)										
	Te	52					$MgTe$	16.02		Hexagonal										
Rare Earth	Ce	58	1.6	0.15 @ 300	590	21	Mg_9Ce (1)	60.97	622						90	9	Up	Down		
	Pr	59	?	?	593	23.5	Mg_3Pr	34.11	798	cubic	7.37									

Notes: (1) Formed by peritectic reaction.
(2) Non-metallic (Mg_2C_3 decomposes water forming C_2H_2, etc.).
(3) Exists in 2 modifications: α at low temperature (non-metallic) and β at high temperature.
(4) Trigonal A of the lanthanide-sesquioxide (Sm_2O_3-La_2O_3) type.
(5) Highly desirable alloying elements: Zn, Al, Ag, Tl, Cd, Ca, Ce, Ga, Th. Possibly desirable Ni and Cu. Not desirable: Sn, Pb, Bi and Sb.

J.C. McDonald, AIME, Institute of Metals Div., vol. 137 (1940) p. 430 and vol. 145 (1941) p. 179.
(6) The second constituent undergoes a change at 327°C. Authors (Hume-Rothery and Gaynor) say nothing about it. Jl. Inst. Metals (London) vol. 65 (1938) p. 201-236.
(7) Rolled
(8) Extruded

* Magnesium; 12; melting point 649°C.; crystal structure: hexagonal close packed, a=3.20259 A.U., c=5.19973, c/a=1.6236; Tensile strength 28,000 Psi extruded, 25,000 → rolled. Mg is electropositive to most metals.

baffle arrangement after coating, to prevent their "freezing" together.

Quenching in oil, followed by tumbling in a sawdust filled barrel, insures a smooth, uniform finish on small parts. Sheet steel is frequently passed through a hot oil bath and wiped clean with sawdust or the equivalent to finish the work properly. Treatment of all work must be governed to a large extent by the ultimate purpose for which it is intended.

One of the outstanding characteristics of the process is its ability to produce work that is free of tear drops, heavy spots, and clogging. It is particularly effective on radiators in which tubes and fins are closely spaced (where there is danger of clogging), and on mufflers which have complicated systems of perforated baffles to be coated completely, inside and out. Cases for portable radios, and other fabricated units, which present a similar problem, are being successfully coated.

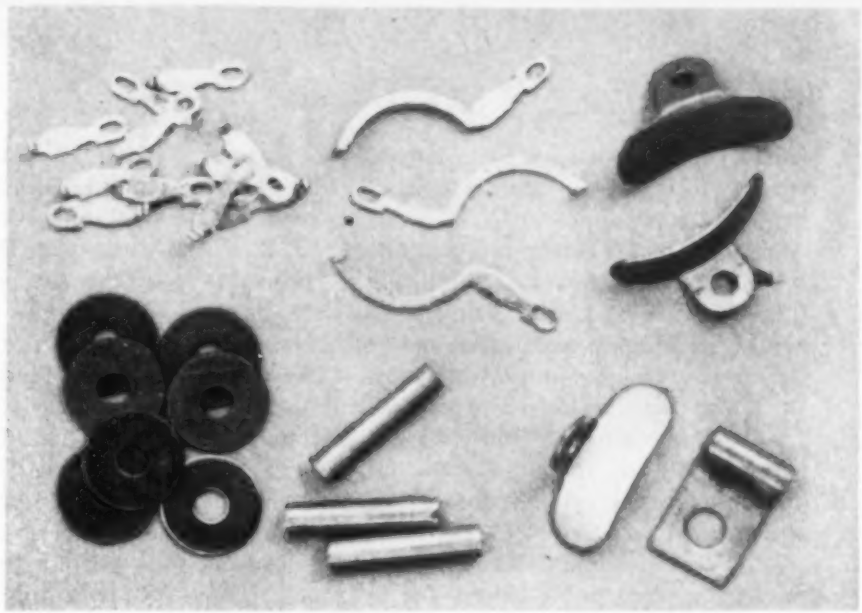


Fig. 2 — Examples of Small Parts, None More Than ½-In. Long, Coated With Lead Alloy Low in Tin. Courtesy Wacho Mfg. Co.

Adaptability of Low Tin Coating

There is no limit, apparently, to the size or type of articles that can be coated by this process. Figure 2 shows very small parts — less than ½ in. long — that have been satisfactorily coated. The coating facilitates soldering operations. Nuts and bolts can be coated uniformly without blocking the threads — in fact, the finished bolt provides a safer, tighter connection than a bare one.

These coatings, because of their anti-frictional property, greatly expedite the deep drawing and other forming of thin steel sheet. The coating acts as a lubricant, permitting deeper draws having a smooth finish. Lead alloy coated sheet can be bent and formed without danger of cracking or peeling, because there is no brittle bonding layer between the alloy and the steel, and the alloy itself is ductile. On draws as deep as 6 in. or even more, no visible cracking or peeling of the coating has occurred.

Lead alloy coatings on large articles, such as metal drums, heating coils, radiators (Fig. 4), gas and oil tanks and similar equipment, offer

Fig. 3 — Medium Sized Boxes Being Cleaned Individually in Line of Tanks at Left; Small Parts Handled in Perforated Baskets at Right. Completed boxes and covers in foreground illustrate smooth finish. Courtesy Master Metalcoaters

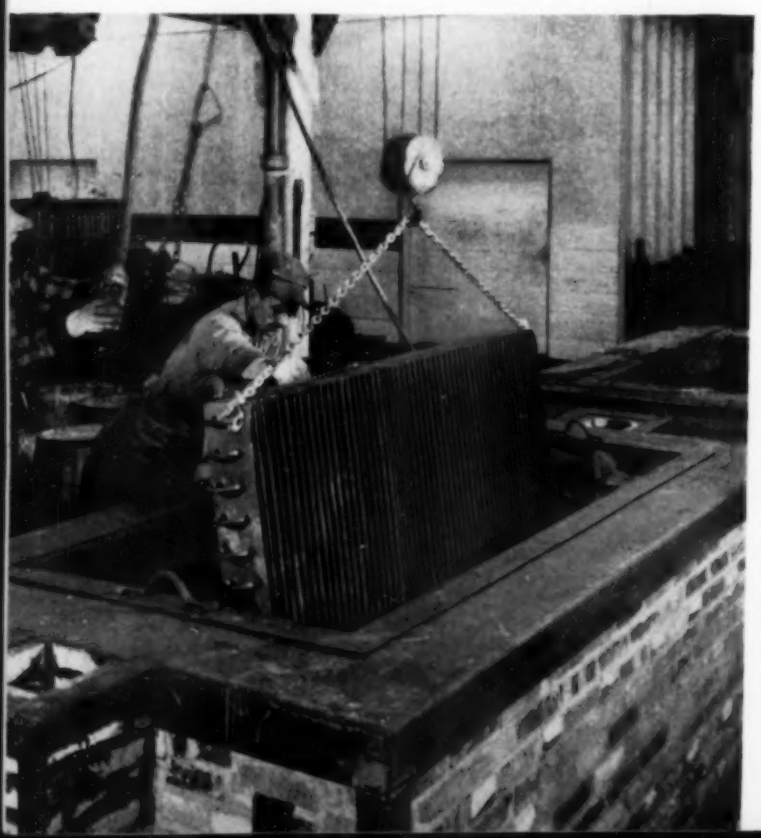
the advantages of ease of application and excellent protection from atmospheric corrosion. The well finished appearance is evident from the completed boxes in the foreground of Fig. 3.

Coating Thickness — Some work, subject to atmospheric exposure, requires a fairly heavy coating. Abrasion resistance, as well as corrosion resistance, is frequently important. These low tin alloys become harder with age. It has been found that while they may be defaced through rough handling, they are sufficiently tough and adherent that scratches rarely penetrate to the steel below.

There are instances in which the coating may be applied fairly thin — for example, if the finished article is to be painted, or if the coating is to afford protection for only a very short period. Furthermore, a thick coating is not needed if the principal purpose is to facilitate a subsequent drawing or forming operation. Each type of work can be coated so as to accomplish most economically and effectively the purpose for which it is intended.

As to the desirable *weights* of coating, thick coatings generally have a disproportionately longer life than thin coatings. W. H. J. Vernon, in an article in *Metal Industry*, Vol. 46 (1935) page 276, entitled "The Protection of Metals by Coatings", attributed this to the fact that thinner coatings are generally more porous than thicker ones. Furthermore, the characteristics of the protective film formed on the coating metal affect the life. It is reasonable to expect that when the metal coating is *very* thin, all or a large part of it will sometimes be used in the formation of this protective film. All protective films formed by nature are non-metallic, and while their solubility in water is very low, the wastage over a period of years can be appreciable. There is also more or less tendency toward erosion of these films upon exposure; as to this, the character of the protective film and the exposure environment are governing factors. Ample coating thickness should be provided, obviously, to protect the article, part or structure as long as may be necessary. A hot dip lead alloy coating weighing 0.7 oz. per sq.ft. minimum (approximately 0.0004 in. thick) is considered completely satisfactory for resistance to atmospheric corrosion.

Fig. 4 — Large Radiator Being Dipped in Flux; Lead Alloy Tank at Left of Workmen. Courtesy Wacho Mfg. Co.



Economics and Post-War Possibilities

From an economical viewpoint the application of these lead alloys offers many advantages. The operating temperature of the alloy pot is low and this results in low fuel costs. Modern practice in the handling of hot dip lead alloy minimizes losses through drossing. Furthermore, since the lead alloys do not attack the steel pot, its life is far greater than with many other coating metals. The anhydrous flux used has a low vapor pressure, and at the usual operating temperature fuming is negligible. Furthermore, the flux is stable and its effectiveness is found unimpaired after long runs; replenishment is needed only to compensate for the small drag out.

Hot dip lead alloy coating was developed prior to the war, and the war provided impetus for its adaptation to many new fields. According to present indications, this metallic coating is so satisfactory that it will find continually wider acceptance after the war, with the release of steel for non-military purposes. At present it is employed in air cleaners, automobile radiator shells, foundry chaplets, can spouts, drawn auto filters, muffler shells, fuel tanks, and radio cases, condenser shells and soldering lugs — to mention only a few. It will be used after the war for these same purposes and also for many others such as air conditioning ducts, fencing, gutters and downspouts, meter boxes, containers of many types, farming equipment and miscellaneous hardware items.

Offering, as it does, so many worth while advantages — economy of production, corrosion resistance, ductility, paintability, and general adaptability — low tin-lead alloy coatings will inevitably continue to increase in importance in the field of metal protection.

Acid Electric Steel-Making Practice

(Notes for Operators)

By Conrad C. Wissmann
SF 3/C
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U. S. Navy

IT IS MY INTENTION to write a simple set of instructions primarily as an aid to those who are engaged in the operation of acid electric steel-melting furnaces. All of the problems discussed herein will have to do with the *operation* of the furnace and the *process* of steel making. It is not written for owners of plants or those who are thinking about installing an electric furnace. The information about the installation of the furnaces, different types of furnaces, power system necessary and other questions which might arise when choosing a suitable furnace for the needs, can be gotten from other sources, notably the distributors and manufacturers of such furnaces. Consequently we will apply ourselves to the problems of *operating* the acid electric steel-melting furnace which we find in the shop.

Charging the Furnace

There are three sources of trouble which a melter can run into in melting down a charge: First he can have trouble making contact, second in pulling bottom, and third from scrap bridging in the furnace. Any one of these can be very serious and lose a lot of unnecessary time. However, if the proper scrap is available and it is placed in the furnace properly, there is little danger of any one of these three causing any trouble.

Most acid electric furnaces are used for making steel in foundries — that is, for production of steel castings. Therefore, usually 30 to 40% of the charge of scrap will consist of heads and gates that are cut off of the castings. The heads are usually charged on the very bottom of the furnace; along with them may be mixed any other heavy or chunky pieces, the heavy pieces being put in first and placed directly under the electrodes. The lighter heads are then charged in on top of the heavier pieces.

A sound rule to go by is to place heavy scrap — that is, scrap which is in large pieces or scrap that will pack compactly — in the very bottom of the furnace. On top of that several types of scrap can be used. "Light plate" is one, that is, plate varying from ⅛ to ¾ in. thick, and in pieces preferably not any larger than 6 in. square. Enough plate should be used to make a layer completely covering the heads or returns which were placed in first. In place of plate, small scrap of irregular shape can be used — that is, any other scrap which is clean and of not too large or irregular shape. Small plate is ideal, if it can be found, since it will pack fairly compactly and will allow the current which travels from electrode to electrode to pass through the charge very easily.

On top of the plate lighter scrap is charged. This can consist of lathe turnings (providing they are short and not bunchy) or any other small pieces of scrap which are clean and which will not offer too much resistance to a current

passing through. In war time the selection of proper scrap is frequently difficult because of official restrictions. Often times material which is dirty or high in sulphur (screw machine scrap or parts or oily turnings) must be handled, and the sulphur later taken care of by refining and slagging. If an unusual amount of oily turnings must be handled it is well to cover the bottom with a thin layer (and most of the sulphur will burn off) and place the rest of it around the banks at the very last.

However the above general principles should rule in the placement of such material as the management is able to secure.

On top of this third layer and to the sides of the furnace is then charged the remainder of the available gates and other returns which could not be used as bottom scrap, due chiefly to their irregular size and shape. No heavy pieces should be put on top, for when the charge melts down they are liable to fall in against an electrode and break it. In any event the "return scrap" — that is, the trimmings and small return castings — should be placed on the bottom or near the outside wall of the furnace, *never* under the electrodes, since return scrap offers a greater resistance to the current arcing from the electrode.

The operator can judge as to the excellence of his own work in placing the charge if he will remember that the furnace should be filled two-thirds to three-quarters the way to the roof when the rated capacity is inside. Chute charging, with the furnace tilted, tends to put too much heavy stuff to the back. It will be labor well spent to hook the big pieces around until they are in the right spot; it is easier to handle them at the very start than to try to pry them loose when the charge is half melted.

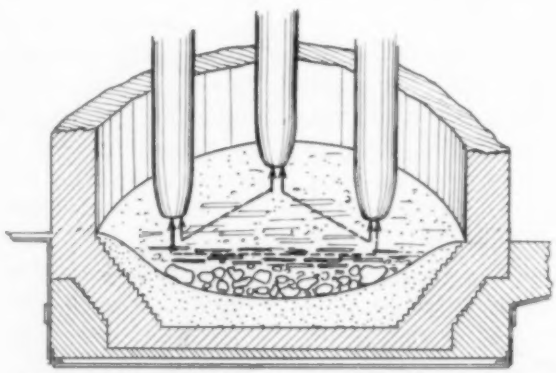

Fig. 1 — Diagram to Emphasize Fact That the Electric Current Must Pass From Electrode to Electrode Through the Charge. Hence it is necessary, for rapid melting of the charge from the bottom up, to have a layer of plate or other closely packed charge near the hearth

Loose charges will tend to increase the power consumption, electrode consumption and melting time — all of them costly items. Proper charging also shields roof and side walls from excess heat reflected from the arc, and therefore reduces the cost and labor of patching, repairs, and relining.

If the furnace has a swing roof and the charge is put in by drop-bottom bucket, the bucket should, of course, be loaded with an eye on the above principles.

Making Contact

Now let us see what happens as a charge melts down, and the reasons for charging the furnace in this manner will become apparent.

The electric current, which is the source of heat required for melting, travels down through the electrodes, and arcs to the scrap underneath. The current which has arced from one electrode to the scrap must then pass through the charge over to another electrode and thence out, back to the power source. The arc across the air from the electrode to the metal produces an intense heat and it is this which melts the steel. It is evident that current must be able to travel through the charge from electrode to electrode as is diagrammed in Fig. 1. Since there must be some layers of scrap in the furnace that can conduct electricity, the scrap in these layers must be fairly clean. It must also be of size and shape so that it will pack tightly enough to carry the current from piece to piece — in other words, that there be no big gaps across which the current must again arc.

Let us assume that in starting up the furnace one of the electrodes failed to make contact. (The operator knows this by looking at the ammeter dial, which would show the passage of very little current to that electrode; also the cable supporting the electrode will start to unwind, allowing the electrode to set down on the scrap.) When that happens all the electrodes must be raised up off of the scrap and contact must be established through the scrap in one of several ways. Sometimes a shovel or two of scale, or coke, or very small pieces of steel such as fine lathe turnings thrown into the furnace on the scrap in between the electrodes and under the electrode which failed to make contact, will help complete the circuit and start the current through.

If this does not overcome the difficulty, a bar should be placed in the furnace running from below the electrode that did not make contact to one that did. This bar should then be covered slightly with some fine scrap. This will generally overcome the difficulty as this bar is a continuous conductor and offers a ready path

for the electricity to pass from one electrode to the other; it will get very hot and melt before long, but by that time the current will usually have found another satisfactory path. If the proper scrap is not available or the scrap is very dirty and of irregular shape so that it will not fit compactly, it is sometimes good practice to place several of these bars between the second and third layer of scrap, to provide a ready path for the current.

Sometimes one electrode will have melted down more rapidly than the others and formed a large hole through the charge to the returns or heads on the bottom of the furnace. It will then "fail to make contact" — the arc will snuff out.

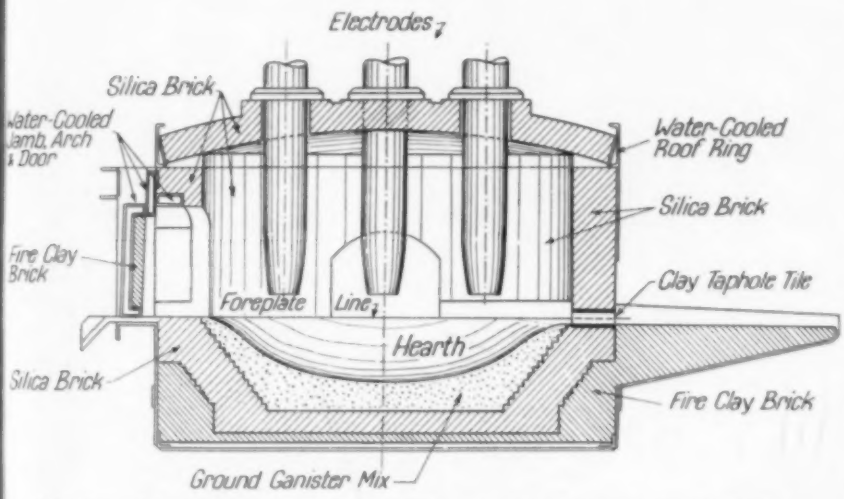

Fig. 2 — Line Drawing of Acid Electric Furnace, a Vertical Section on Center Line, Showing the Nature of the Refractory and Brick Lining (Courtesy American Society for Testing Materials)

The return scrap, since it is seldom cleaned of molding sand, offers greater resistance to current passing through.) The electrodes should then be raised, clean scrap put into the holes which the electrodes have melted, and the furnace started up again. This may have to be done several times until enough steel has been melted down upon the heads to make a pool and form a good path for the current.

In selecting scrap to be charged into a furnace, care must be taken therefore to have enough scrap which is free from dirt and is of a size and shape so that it will pack compactly enough in at least three mounds, one under each electrode, so that current can pass through it. If the proper scrap is available and correctly used very little trouble will be encountered with electrodes failing to make contact. Likewise there is very little trouble in making contact when a furnace is in continuous operation, since the hearth is kept hot and a hot hearth is a fairly good conductor of electricity. When a furnace is run only on one shift however, it will cool off over night and give some trouble the next morning. This may be helped by charging the furnace the last thing, at the end of the shift, turning on the current and letting it run for about 5 min. This will melt and stick together many points of contact in the charge and make it easier for the furnace to make contact the next morning when the hearth is cold.

Pulling Bottom

At the beginning of a heat the electrodes will melt their way down through the charge; that is, they will melt a hole slightly larger than their diameter, down through the scrap. By the time they have melted their way down to the hearth of the furnace, they must have melted enough of the scrap to have formed a pool of molten metal in the flat bowl that is the bottom of the furnace, and this pool should be big enough so the edges are out underneath the electrodes. Otherwise the arc will not flow into any metal but break on the sand or hearth of the furnace. Since the conductivity of a non-metal increases with its temperature, the hearth of a furnace is a fairly good conductor of electricity if it is hot, but an electrode arcing to the hearth will melt and bore a hole down into it. If this condition should be suspected it can always be known by watching the smoke coming out around the top of the furnace doors and the electrode ports. When the arc is breaking on metal the smoke will be a dirty brown: when the arc is breaking to the hearth a white smoke will appear.

This is the first sign that the electrodes are "pulling bottom", as it is called. It is not necessarily a sign of immediate danger since whitish smoke may be from the melting of sand-covered return scrap which is on the bottom of the furnace; likewise, scrap which is high in silicon and manganese will always give off a white smoke when it is melting.

However, if bright yellow flames should come out around the doors or around the electrode ports, it is a positive indication that the electrodes are pulling bottom. Electrodes should then be raised up out of the charge and clean scrap

thrown into the holes that have been bored down through the charge. This may have to be repeated until enough metal has been added and melted to form a pool extending out under the electrodes so that they will arc to the pool and not to the hearth of the furnace. This makes it clear why the hearth should be relatively flat; there are other reasons for a shallow bath, but a deep hole or cup in the center of the hearth will give continual trouble with pulling bottom until it is filled and patched.

If enough heavy scrap is used and it is packed compactly enough on the bottom of the furnace, there is very little danger of pulling bottom. However, if the furnace is not charged properly and there is not enough heavy scrap put under any one of the electrodes, there is danger of the electrodes burning a hole in the hearth of the furnace. Sometimes there is no heavy scrap in the stock yard.

Scrap Bridging

Sometimes, when the heat is far enough along for a pool of metal to have been formed on the bottom of the furnace, the furnace man will notice that the upper layers of scrap are not falling in; that is, there will be a pool of metal on the bottom of the furnace but most of the charge will have stuck together to form a bridge over the pool. This is a very serious condition.

There are two ways to get rid of this bridge. The first would be to thrust bars through the furnace doors and try to break loose the scrap which is stuck together on top, so it will fall into the pool. In extreme cases this can't be done. There is only one thing to do then and that is to add more metal so it can melt into the pool until its level is high enough to melt down the scrap which has bridged on top. This also takes a lot of time and labor to put in a lot of metal, by hand, at the right places, melt it, put in more metal, and so on.

Bridging is usually caused by allowing an electrode to pull bottom. If this is the reason there will be an excess of slag on the metal after it has all been melted. This slag will be thick (sticky) and the electrodes will have difficulty arcing through it. Enough ore should be added to thin out this slag — that is, make it less viscous, more liquid. When it is thin enough the furnace should be tipped over enough to allow this excess slag to run out the tap door.

If this slag is not removed, the carbon content of the heat is very likely to rise as the heat progresses. The electrodes will have such difficulty in arcing to the pool that sometimes their ends will dip down into the slag. If this happens the carbon from the electrodes will be dissolved by the slag and later enter the metal bath.

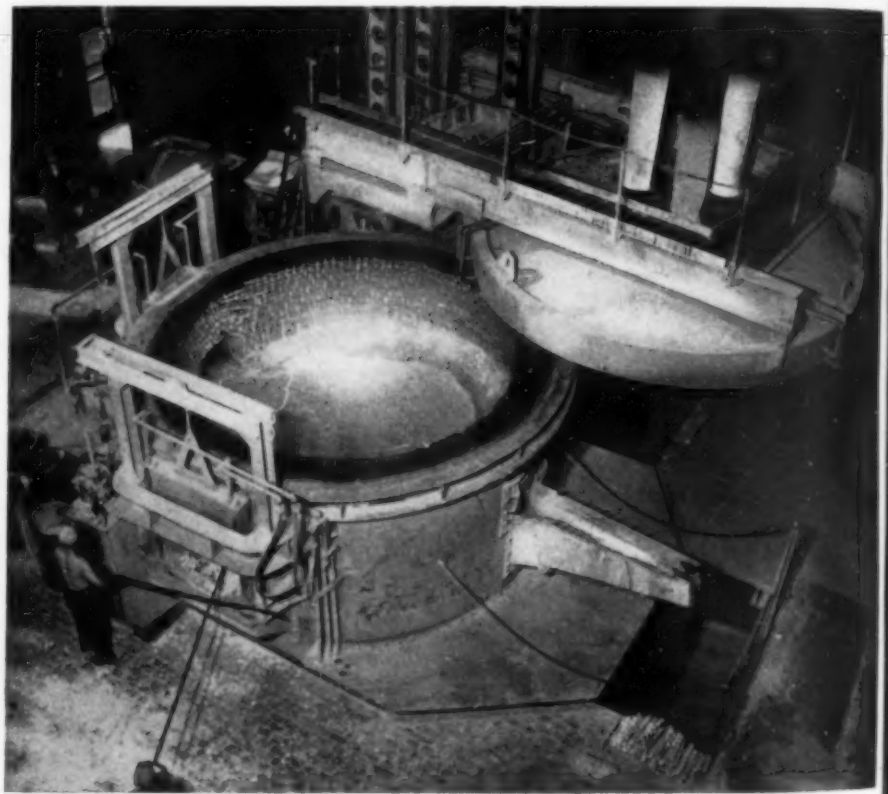

Fig. 3 — View of Large Electric Furnace With Swinging Roof so It Can Be Top-Charged From Bottom-Dump Buckets. Roof swung aside for trick photograph showing hot side walls and slag covered steel on the hearth. Courtesy Allegheny Ludlum Steel Corp.

Bridging can also occur if the heavy scrap on the bottom is not packed closely enough. Also some types of scrap will bridge more readily than others; for example, plates are very susceptible to bridging. Also, long pieces of scrap placed in the second or third layer of scrap will hinder the uppermost scrap from falling into the molten part of the bath.

Endurance of NE Steels in $1\frac{3}{4}$-In. Specimens

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and T. V. Buckwalter
Vice-President
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THE LIMITED DATA on the fatigue resistance of the National Emergency (NE) Steels has been obtained from tests of the conventional R. R. Moore rotating beam specimen with a critical test section about ¼-in. diameter. Objection to such data is not confined to the *size* of cross-section but also to the *shape* of the specimen.

It is customary to use two shapes of such small specimens. One has a longitudinal cross-section described by a radius about 20 to 40 times the diameter of the specimen, a shape representing a condition of no stress concentration which is seldom obtained in actual design members or machine parts and therefore gives fatigue values which are "ideal" in that they are too high. The second specimen shape is often one having a circumferential V-notch with a relatively small radius at the bottom of the notch, and while some practical conditions may approach the severity of stress concentration represented by such a sharp notch it is admittedly poor design.

Between these two specimen shapes is a region which simulates good design practice and it is in this region that a knowledge of the fatigue resistance is of most value in the selection of steels and heat treatments. The question always arises as to how the fatigue values obtained from such small and arbitrarily shaped specimens may be applied to design members which are generally of much larger cross-section. This problem has occurred with great frequency in the last few years because of the use of NE steels.

In order to obtain some information bearing on this problem, fatigue tests were made on $1\frac{3}{4}$-in. diameter specimens from four different

Table I — Chemical Analysis of Steels Investigated

Steel	C	Mn	P	S	Si	Cr	Ni	Mo
S.A.E. 4340	0.44	0.80	0.014	0.018	0.26	0.75	1.75	0.25
NE 8744	0.43	0.84	0.016	0.025	0.24	0.51	0.54	0.24
NE 8949	0.46	1.06	0.014	0.017	0.26	0.56	0.57	0.33
NE 9445	0.44	1.18	0.017	0.020	0.46	0.33	0.52	0.12

Table II — Physical Properties of the Steels in the Endurance Specimens

Steel	Tensile Tests				Izod Impact	McQuaid-Ehn Grain Size		Oxidation Grain Size (1550° F.)
	Yield	Ultimate	Elongation	Reduction of Area		Hot-Rolled	Normalized	
S.A.E. 4340	132,000	144,900	17	58.1	57-58-58	8	8	8
NE 8744	119,100	137,300	17	58	30-30-30	7 to 8	7 to 8	8
NE 8949	136,200	150,500	16	58	53-54-54	6 to 8	7 to 8	8
NE 9445	102,700	122,800	21	59.5	53-54-54	8	8	7 to 8

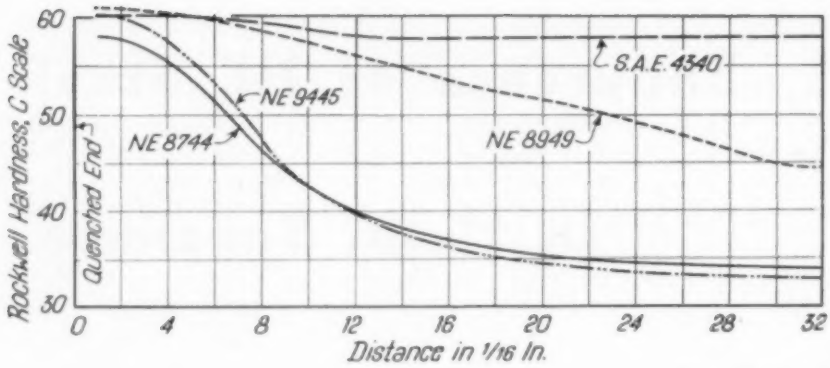


Fig. 1 — Jominy Hardenability Curves for Steel Bars Whose Endurance Was Investigated

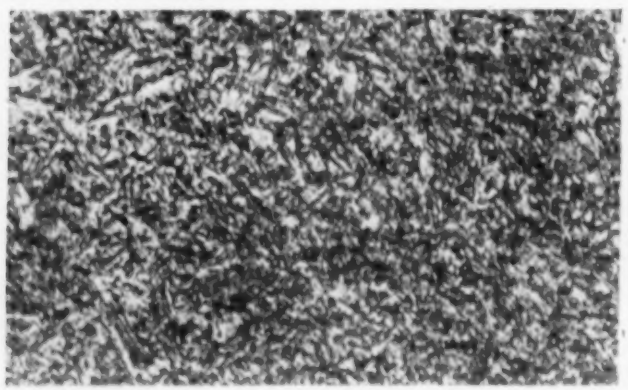
steels. Chemical analyses of the three NE steels selected in comparison with S.A.E. 4340 are shown in Table I. Specimens tested, representative of the steel investigated, were taken from single heats of the four steels. The NE8744 and NE8949 were openhearth heats while the NE9445 and S.A.E. 4340 were electric furnace heats. All heats were cast in 21-in. diameter fluted ingots in inverted, hot-top molds; ingots weighed about 6000 lb. Specimens were taken from 2¼-in. rounds rolled from these ingots.

A non-metallic rating was made on four samples from each heat. All heats were found to be of satisfactory quality, having a rating of "fairly good" to "fair". McQuaid-Ehn grain size samples were obtained on all materials in both the hot-rolled and normalized conditions. Oxidation grain size results are also given in Table II. Jominy hardenability tests are shown in Fig. 1.

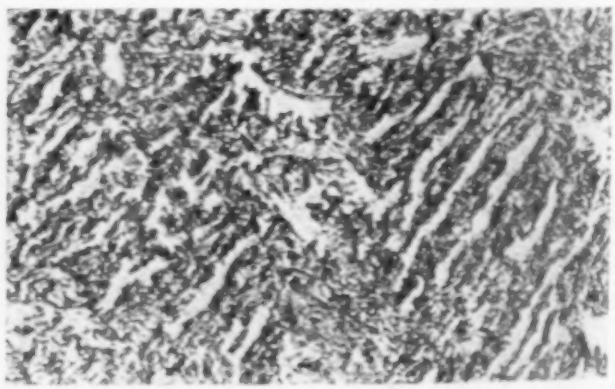
All specimens were quenched and tempered to the same hardness, Brinell 302 or Rockwell C-31. Physical properties obtained on ¼-in. tensile specimens machined from the outside of the large end of fatigue specimens are also given in Table II. The fatigue specimens were rough machined to shape, allowing $\frac{1}{16}$ in. on a side for machining after heat treating. All four steels were oil quenched from 1500° F. into a full oil spray with an oil temperature of 72 to 90° F. and then tempered for 4 hr. at temperatures shown

Fig. 2 — Microstructure of Fatigue Test Specimens Taken Near Their Surface, at 1000 Diameters. All samples were oil quenched from 1500° F. into a full oil spray and tempered for 4 hr. to give equivalent hardness, 302 Brinell or Rockwell C-31

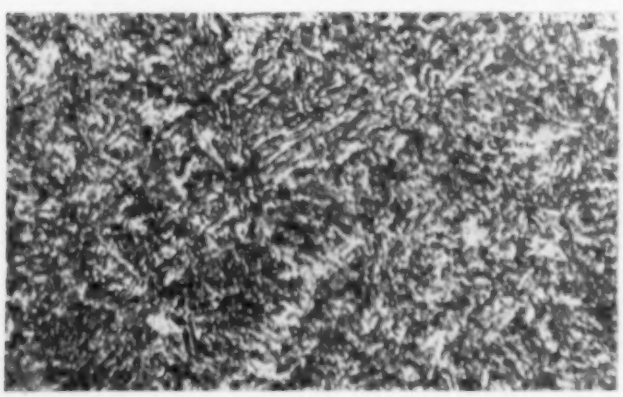
S.A.E. 4340, Tempered at 1100° F.



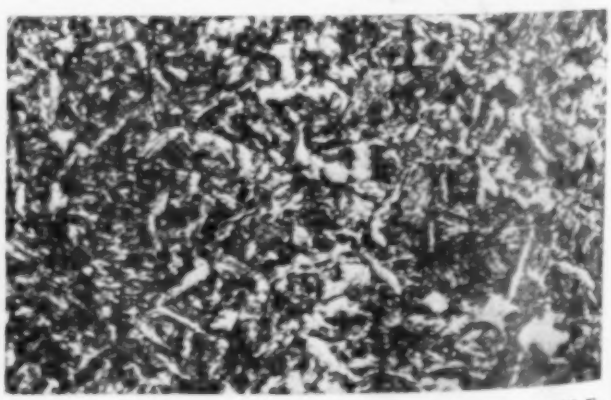
NE8744, Tempered at 1025° F.



NE8949, Tempered at 1075° F.



NE9445, Tempered at 1025° F.



on the micrographs, Fig. 2.

Two general shapes of specimens were tested. One shape incorporated a fillet at the test section; four different fillet radii were investigated, $\frac{3}{32}$, $\frac{9}{32}$, $\frac{3}{4}$ and $9\frac{7}{8}$ in., as shown in Fig. 3. The second shape has a circumferential circular notch; four different notch radii of the same magnitude as the fillet radii were investigated, as shown in Fig. 4. All specimens were tested as rotating cantilever beams at a speed of 1400 to 2200 rpm.

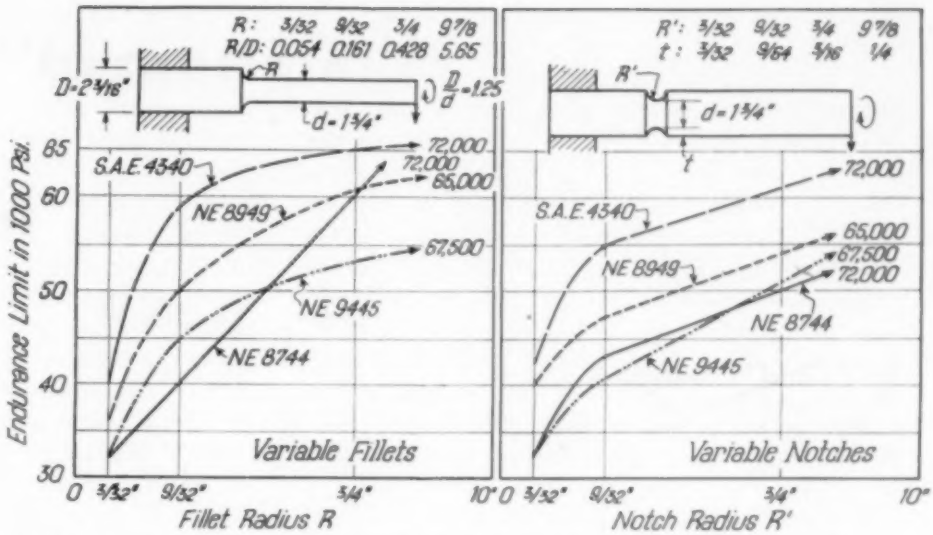


Fig. 3 and 4 — Fatigue Strength of Round Cantilever Beams of Four Important Steels, as Affected by Fillet Radii and Notch Radii

Table III — Fatigue Strength Values of Four Steels with Different Shapes, Based on 30,000,000 Revolutions

Shape of Specimen *(a)*		Fatigue Strength in Psi.			
R, in.	Type	S.A.E. 4340	NE8744	NE8949	NE9445
9⅞	Plain	72,000	72,000	65,000	67,500
¾	Fillet	65,000	60,000	61,000	53,000
	Notch	61,000	50,000	54,000	51,000
9/32	Fillet	59,000	40,000	50,000	45,000
	Notch	55,000	43,000	47,000	41,000
3/32	Fillet	40,000	32,000	36,000	32,000
	Notch	42,000	32,000	40,000	32,000

(a) Shape of specimens shown in Fig. 3 and 4.

Profilometer readings made on these specimens showed 5 to 20 micro-inch surface finish. All specimens were polished circumferentially using a rotating canvas wheel loaded with different grades of alumina.

The endurance limit values for the four steels and both fillet and notch conditions are given in Table III on the basis of 30,000,000 revolutions, instead of the usual 10,000,000. These fatigue values are also plotted in Fig. 3 and 4.

Fatigue values shown in Fig. 3 and 4 in the notched range of $\frac{3}{32}$ to $\frac{3}{4}$-in. radius represent the region of most interest to the metallurgist and designer. Many design members should fall within this zone, since they have stress concentrations comparable to these fatigue specimens. One should know, but seldom does, the exact degree of stress concentration present in any design; in any case, the curves in Fig. 3 and 4 comprise a better determination of the fatigue characteristics of the different steels (under the various conditions of geometry which are usually found in good design practice) than is contained in the endurance figures for small smooth specimens.

These four steels with the different degrees of stress concentration as represented by the three different fillets and notches may be rated over this region of geometry as follows, on the basis of these tests and from the standpoint of fatigue endurance limit:

S.A.E. 4340	100% in all conditions of geometry
NE8949	94% maximum to 85% minimum
NE8744	92% maximum to 68% minimum
NE9445	85% maximum to 75% minimum

Little emphasis is placed on the endurance limit values of the plain specimens having the 9⅞-in. radius, for the reasons mentioned before. In fact the values given here for this extreme case are believed to be on the low side — particularly for S.A.E. 4340 and NE8949. If a longitudinal polish instead of the circumferential polish were used it is believed that the endurance limits of these two steels in plain specimens would be increased by 10 to 15%. On this same basis the "ideal" value for NE8744 may be increased about 5% over that listed for the plain specimens, but little change would be suggested for the NE9445. This estimate is based on the scatter of results obtained in the individual fatigue tests of these steels. Specimens having a $\frac{3}{32}$ to $\frac{3}{4}$-in. radius would probably be improved by a longitudinal polish not more than 5% of the values given in Table III.

"Interrupted" Quenching in Salt Baths

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The interrupted quench has been used in various modifications for a number of years to reduce cracking and internal stresses. The practice formerly consisted of a timed quench for a short period in an intense medium followed by transfer to another furnace, or by air cooling from the timed quench, which completes the transformation at a very much slower and more uniform rate. "Martempering," "Austempering" and "Isothermal Quenching" are names applied to controlled interrupted quenching in hot baths. The quenching speed of molten salt—now used for the purpose—has been underestimated, as only recently has the true value of salt bath quenching speed been known.

FEW STEELS can offer full value to engineers today unless given suitable thermal treatment. These treatments include softening for deep drawing or good machinability, producing high tensile properties with good fatigue or impact values, or high hardness so that the steel thus treated may be used in machining other steels.

Engineers are now demanding parts to be heat treated for

1. Higher desired physicals.
2. Minimum of dimensional changes, distortion or warpage.
3. Minimum of residual strains to increase fatigue life and impact value.
4. A heat treating technique that produces parts free of scale, surface decarburization or carburization.
5. Parts that can be finish-machined and then heat treated for high physicals, meanwhile holding the parts to close dimensional tolerances.

Steel is not the big bull in the woods which shows no signs of abuse. Instead it is temperamental; if not treated correctly, it may reflect this lack of care in the form of cracks which will cause it to break down under severe service. But if it is properly treated, it can be an able servant of industry.

It is of course possible to change the properties of steel considerably by heating and cooling it under certain definite conditions which can be reproduced. When heating or cooling steels of varying carbon and alloy content, definite and characteristic changes in dimensions and in microstructure take place at the critical temperatures. To be fully acquainted with these changes, it may be timely to review briefly what occurs when a piece of steel is heated.

Before we are able to determine the proper heat treating procedure to obtain the most desirable properties for any particular steel, the heating cycle, cooling cycle, and the element of *time* at one or more temperatures must be taken into consideration. "Heating cycle" includes not only the raising of the temperature but the stay at high temperature. This first step in martempering and austempering—indeed in any true "quench"—is to heat the material to some temperature either in or above the critical or transformation range in order to transform alpha into gamma iron and put the steel in the austenitic condition. Carbon and other alloying elements will thus be dissolved in a solid solution of the

gamma iron, to form homogeneous austenite, given time and temperature enough. This solution of elements may be either complete or partial, depending on the time-temperature cycle. Complete diffusion into a truly homogeneous austenite is a time consuming process.

During this heating cycle there are definite dimensional and microstructural changes taking place at the so-called critical temperature. As steel is heated, a steady thermal expansion takes place as the temperature increases until the critical is reached, whereupon a contraction in volume accompanies the heat-absorbing transformation as the metal passes through the critical range. Differences in the speed at which temperature rises or austenizing temperature is reached — as between thick and thin sections of parts of variable cross-section — cause distortion, warpage and differences in austenitic grain size. However, the *rate* of heating is not as important as obtaining a uniform austenizing temperature, and determining and holding the proper maximum temperature for the proper period of time.

High Temperature Soak

Time requirements for diffusion to obtain homogeneous austenite vary somewhat, depending upon the chemical composition. Elements diffuse at different rates. Many alloy steels are "sluggish" and require a longer soaking time at the austenizing temperature; often the temperature may be raised to accelerate diffusion without undue coarsening of the grain.

The actual heating temperature should be somewhat above A_{3-2}, the upper critical temperature, to assure homogeneous austenite. When heated too long after complete solution occurs, an increase in the austenitic grain may result. Some steels coarsen much more rapidly than others. A higher temperature than necessary has the same coarsening effect, although with "fine grain steels" (which are really steels that start to coarsen at relatively high temperatures) this is less dangerous than too low a temperature. *Complete* austenizing may not be desirable in hypereutectoid steels, but the pearlite should always be transformed into austenite as homogeneous as possible. When in doubt of the correct temperature, the metallurgist lacking experimental equipment can consult several reference books, *Metal Progress* Data Sheet No. 21, or request this information from the source of his material.

Uniform austenite places the steel in proper condition to respond to cooling. It is now ready to quench.

To gain an understanding of what occurs when steel is cooled and the effect of different cooling rates, it is necessary to know the time required for decomposition of austenite at various temperatures, and what the resulting microconstituents will be. This can best be summarized by the S-curve (often referred to as the time-temperature-transformation or "TTT-Curve") as originally developed by Davenport and Bain and described in their important paper entitled "Transformation of Austenite at Constant Subcritical Temperatures" in *Transactions* of the Iron & Steel Division, A.I.M.E. in 1930. Their S-curve for plain carbon, eutectoid steel is reproduced in the data sheet on page 840.

The horizontal ordinate represents time expressed on a logarithmic scale. This scale is used for convenience because the range of time at the several constant temperatures is very large. The vertical ordinate represents the temperature at which the transformation is taking place. The pair of S-curves (so-called because of their fancied shape) locate the temperature and time interval required for the beginning (left curve) and the completion (right curve) of the transformation at constant temperature.

In other words and purely for example, if such a eutectoid steel were to be cooled quickly — almost instantly — from some temperature above the critical to, say, 950° F., the austenite would start to transform within 1 sec. and would be completely transformed in about 9 sec. (the intersections of the 950° horizontal with the left and right curves respectively). Likewise if the steel were to be quickly cooled past this "nose" of the S-curve down to 500° F., transformation would not even start until about 4 min. had elapsed and would not be completed for an hour.

As shown by the micros at the respective positions in this data sheet, the structure above the Ae_1 temperature and to the left of the left curve is austenite. The micrographs also show the structure resulting from partial or complete transformation at various constant temperatures.

The curve shows that transformation is not instantaneous at any temperature. It predicts the time required at any constant temperature for transformation to begin and be completed. However there are two temperature ranges where transformation takes place very fast in this plain carbon steel; one is the vicinity of 1050° F. and another at about room temperature.

Depending on the time and temperature at which austenite decomposes, the ultimate structure results in three different reaction products:

1. If the transformation takes place in the higher temperature range above the nose of the

S-curve (about 1050° F.) the product is lamellar pearlite. The closer the temperature at which transformation occurs is to 1050° F. the finer and harder will be this pearlitic structure, until at and slightly below the nose of the S-curve the structure is a very fine lamellar pearlite (often called "primary troostite"), and usually occurs in the microstructure as roundish, rapidly etching spots warranting the name of "nodular pearlite".

2. In the intermediate transformation range, say from 900 down to 500° F., if the method of quenching causes transformation to take place between the temperature of the nose

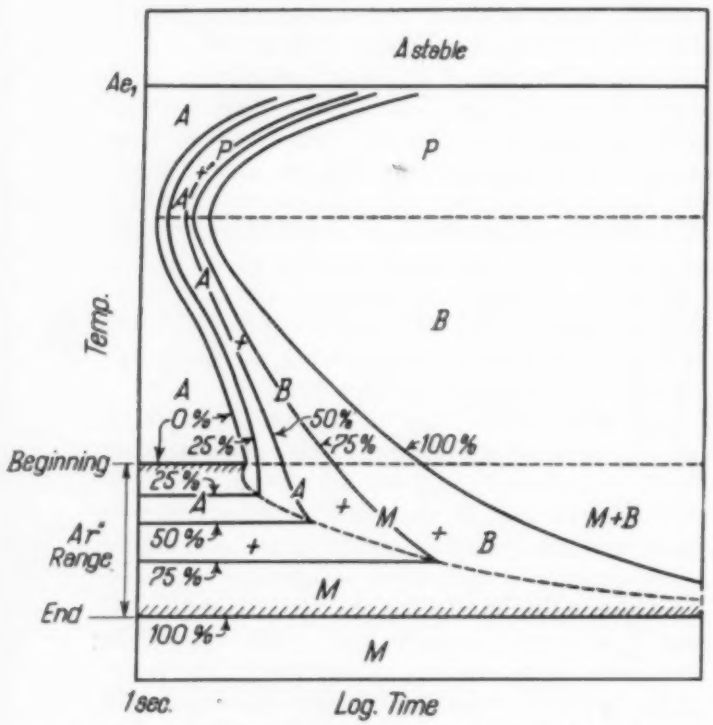


Fig. 1 — Modified S-Curve to Diagram the Transformation of Austenite Into Martensite, According to Cohen, Transactions ASM, September 1940, Page 565

A = Austenite
P = Pearlite
B = Bainite
M = Martensite or Tempered Martensite

of the S-curve and the temperature at which martensite starts forming (the M_S point, so called) austenite decomposes to an acicular structure called "bainite" (named after Dr. Bain). The lower the temperature at which transformation takes place, the more acicular, finer and harder is this structure. "Austempering", as specified in U. S. Patent 1,924,099 to Davenport, Roff and Bain, is a controlled time quench which brings the hot steel quickly into this intermediate temperature range and holds it at constant temperature for the correct time.

3. Contrary to former belief, austenite transforms to martensite while cooling through a temperature range rather than being a "trigger-type" reaction going rapidly to completion, once it is started. For convenience this martensite transformation range has been called the Ar" range; the temperature at which martensite starts forming is termed the M_S point, and the point at which transformation is finished is the M_F point. Morris Cohen has devised a schematic S-curve which well serves to present these facts about martensite formation. See Fig. 1.

Carpenter and Robertson's work in England, contained in their two volumes entitled "Metals", has shown that austenite undoubtedly transforms to martensite as the temperature drops through a range which is characteristic for most of the commercial carbon and alloy heat treated structural steels. When the steel is quenched by exceeding the critical cooling rate — that is to say, at such a speed that no austenite has time to transform between 1150 and 850° F., the region of the nose of the S-curve — transformation of austenite is suppressed until the M_S point is reached; formation of martensite then starts and continues as cooling progresses. When the M_F point is reached, the austenite is practically completely transformed to martensite. (In some toolsteels and in high alloy steels a certain amount of austenite is retained untransformed after the quench.)

If in the process of quenching the cooling is interrupted at some temperature within the martensitic transformation range, then transformation stops. If a constant temperature is held, isothermal transformation will start after some little time and progress slowly, but the time required for complete transformation would take too long for this scheme to be of any practical use in commercial heat treating. If, after interrupting such a quench, cooling is then continued, austenite will again continue to transform to martensite until substantially completed.

A paper presented on "Kinetics of the Austenite to Martensite Transformation in Steel" by Greninger and Troiano before the ASM (see *Transactions*, September 1940, page 537) confirms Carpenter and Robertson's work. In the conclusions of their paper they state:

> "1. Martensite will begin to form as soon as the specimen temperature reaches the upper limit of its martensitic range.
>
> "2. Martensite will continue to form as the cooling proceeds.
>
> "3. A slight amount of martensite may be formed after the specimen has attained temperature equilibrium. This is a minor effect, however, in comparison with the martensite formed during cooling."

Louis Carapella (*Metal Progress*, July 1944, page 108) has devised this formula to determine the M_S point of a steel from its chemical analysis:

$M_S = 925° \text{ F.} \times f_C \times f_{Mn} \times f_{Si} \times f_{Ni} \cdots\cdots$

wherein the factors for the various elements are computed as follows:

$f_C = 1 - 0.620\%$ carbon
$f_{Mn} = 1 - 0.092\%$ manganese
$f_{Si} = 1 - 0.033\%$ silicon
$f_{Ni} = 1 - 0.045\%$ nickel
$f_{Cr} = 1 - 0.070\%$ chromium
$f_{Mo} = 1 - 0.029\%$ molybdenum
$f_W = 1 - 0.013\%$ tungsten
$f_{Co} = 1 + 0.120\%$ cobalt

This shows that the carbon has by far the greatest effect in depressing the M_S point; manganese, chromium and nickel are less effective, and silicon, molybdenum and tungsten the least effective.

Knowledge about the position of M_S is most essential in determining temperatures for the interrupted quench. Very little work has been contributed whereby we might determine the M_F point, where transformation is completed. For most commercial steels it is above room temperature; however, there are a number of high alloy steels, such as carburized A.I.S.I.3300 series and high speed toolsteels, in which the M_F point is lower than atmosphere temperatures. In such steels which retain some austenite on reaching room temperature, the principle that "transformation takes place through a temperature range" still applies; in order to obtain complete transformation to martensite they may be cooled to some sub-zero temperature.

Steels cooled by the usual quench in oil or water are transformed during the cooling. They do not transform at the same rate and time, surface to center, as occurs when holding at a constant temperature, thus permitting isothermal transformation. It has been found by Grange and Kiefer ("Transformation of Austenite on Continuous Cooling and Its Relation to Transformation at Constant Temperature", *Transactions* March 1941) that transformation during continuous cooling and isothermal transformation have a definite relation which can be evaluated. If transformation curves for continuous cooling and constant temperature be superimposed, the curves representing beginning and end of transformation during continuous cooling in commercial quenches will be somewhat below and to the right of the constant temperature or isothermal curve. Since it has been determined that there is a definite relationship between the two types of cooling, the isothermal diagrams, 47 of which are available in U. S. Steel Corp.'s "Atlas of Isothermal Transformation Diagrams", can be used with a reasonable degree of accuracy to predict the time-temperature and the resulting product. Liedholm has presented a method whereby a continuous cooling transformation diagram can be constructed from a series of Jominy end-quench test bars, and such diagrams for S.A.E.6135, 4330 and NE8630 appear in data sheets in *Metal Progress* for January, June and September 1944 respectively.

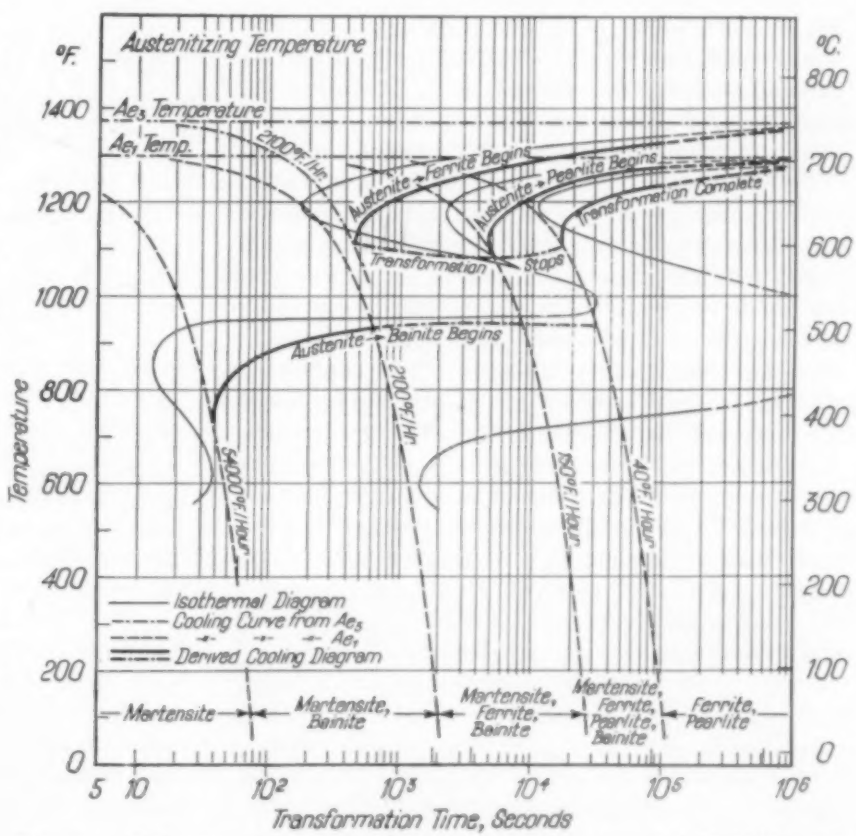


Fig. 2 — S-Curves (as Shown in Light Lines for S.A.E.4340) Are on the Basis of Instantaneous Cooling to a Certain Temperature and Holding Constant. Actual cooling of sub-surface regions, during commercial quenching, is at a more or less uniform rate — at least for the first stages. This causes the actual commencement and completion of the transformations to occur at slightly lower temperatures and considerably longer times. (Grange and Kiefer.) Ultimate microstructures are noted in the line at the bottom of the sketch

Figure 2 is Grange and Kiefer's diagram showing the beginning and completion of transformation for S.A.E.4340, which reveals the above mentioned relationship between transformation during constant cooling, and isothermally.

The interpretation of the various cooling rates in regard to time-temperature and the resulting products can be illustrated by the schematic Fig. 3, taken from Grossmann's book "Principles of Heat Treatment", 3rd Edition, page 135. The thermal history of a steel cooled at a very slow rate, as in annealing, is indicated by curve *B*. When the steel reaches the temperature at B_1, transformation to pearlite begins, and as cooling proceeds, transformation continues. When the temperature reaches B_2, the transformation is completed. The pearlite first formed at the upper temperature B_1 will be coarser and softer than that formed at temperature B_2. The hump part of the cooling curve shows that a certain amount of heat is liberated, due to the transformation of austenite into pearlite.

A more rapid rate of cooling, as in normalizing, or air cooling, is indicated by curve *C*. The steel transforms into pearlite similarly to that in curve *B*, but the pearlite which is formed at C_1 will be finer and somewhat harder, and the pearlite formed at C_2 will be still finer and harder.

With a still faster rate of cooling as in water, indicated by curve *D*, the start of the austenite transformation is suppressed even further, and a slight heat evolution is noticed in a precise cooling curve at about 1050° F. At this point some of the austenite transforms into nodular pearlite, often termed primary troostite. The remaining austenite is prevented from transforming until the temperature falls to the M_S point or D_3, when martensite begins to form in a process which is completed at the M_F point or at about room temperature. The resulting microstructure will be a mixture of fine pearlite and martensite. The product from cooling curve *E* will be somewhat similar to that from curve *D*, except that more martensite and less pearlite is formed.

With an accelerated cooling curve *G*, as in iced brine, which exceeds the critical cooling rate, no austenite will transform into pearlite; transformation will begin at the M_S point and be completed at the M_F point G_3. This results in the formation of a fully martensitic structure and maximum hardness.

As pointed out above, there is a *minimum rate* of cooling at which *maximum hardness* in any given steel can be attained. This rate of cooling just skirts the nose of the S-curve, and is termed the critical cooling rate. The critical cooling rate of carbon steels is known to vary with the chemical composition, grain size, and the details of manufacture such as method of deoxidation. Increase of carbon content from 0.20 to 0.83% lowers the critical cooling rate—that is to say, the low carbon steel must be quenched much more drastically than the high carbon steel if the maximum hardness is achieved of which it is capable. With increase in carbon content above 0.83%, the critical rate increases slightly.

Addition of alloying metals greatly affects the critical cooling rate of the steel (some, such as vanadium, have very little effect). Nickel, manganese, molybdenum and chromium lower the speed of cooling required for full hardening. Figure 4 shows the comparative initial trans-

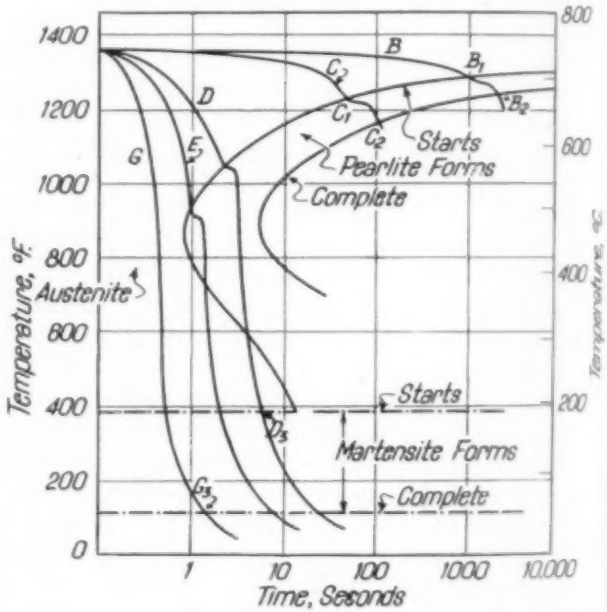


Fig. 3—Cooling Curves for Various Operations From Furnace Anneal to Iced Brine Quench Are Shown in Relation to Those Portions of the S-Curve That Locate the Formation of Pearlite and Martensite (After Grossmann; Lower ends of curves D, E and F are changed)

formation temperatures of plain carbon 0.50%, S.A.E.5140 (chromium) and 4140 (chromium-molybdenum) steels. This shows that as alloying elements are added to increase the hardenability, the position of the S-curve is moved to the right, lowering the critical cooling rate by widening the gap at the nose of the curve. Full hardness requires cooling below the nose of the S-curve in less than 1 sec. for the 0.50% carbon steel, approximately 2 sec. for S.A.E.5140 steel with 0.90% Cr, and nearly 3 sec. for S.A.E.4140 steel with 1.00% Cr and 0.20% Mo. This well illustrates the fact that if the hardenability of a steel is increased, the position of its S-curve is moved

to the right and the critical cooling speed is slower. There is, therefore, a definite relation between the position of the S-curve and hardenability.

The slow critical-cooling rate of alloy steels has many advantages, since maximum hardness can be obtained with a less drastic quench, larger pieces may be quenched to full hardness, higher fatigue and tensile strength and greater toughness.

The influence of the cross-section of the part being quenched must continually be borne in mind while considering any heat treating process. The microstructure produced is in a large measure related to the rate of cooling and it is evident that under any given set of conditions large sections will cool at a slower rate than thin sections. Equivalent final structures can only be had by using a faster quenching medium to neutralize the effect of larger sections, or by changing to a steel with a slower critical cooling rate.

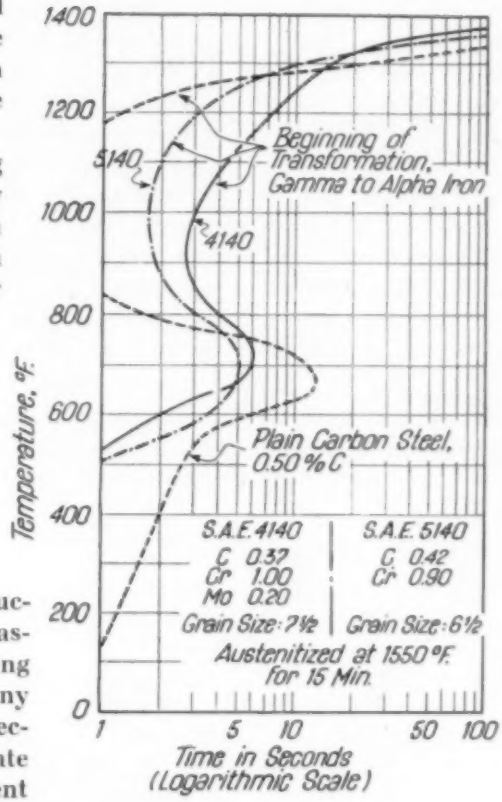


Fig. 4 — Comparative Curves Locating Start of Transformation at Various Temperatures for a Plain Carbon Steel and Two Alloy Steels

The size of section and the severity of the quench have an influence in the occurrence of the common quench crack and the less familiar microscopic cracks. Figure 5, taken at 1000 diameters, shows martensitic cracks in a carburized part quenched cold in water. Note that there are at least ten cracks across the one martensitic needle. Each crack lowers the ductility and fatigue life of the part, resulting in early failure. Martensitic cracks are caused by internal cooling strains and are often accompanied by warpage and distortion. Martempering, austempering and the interrupted quenches eliminate these "gremlins" in heat treating.

Effects of Quenching Media

The cooling curves of the outside and center of similar pieces quenched in water, oil, air and salt and the process of transformation by these various quenching methods are illustrated in Fig. 6. In each case, the quenching speed exceeds the critical cooling rate of the steel being quenched, making it compulsory for martensite to form. The quenching rates are seriously affected by a natural law relating to the mass of the part, which causes the interior portions to lag behind and cool slower than the outside. The faster the quenching speed, the greater the temperature differential between the surface exposed to the coolant and the center.

With a very rapid quench, such as shown by the curve for water quenching, there is a notable temperature difference between the outside and center, measured by the distance between curves at any time ordinate. As illustrated by Fig. 1, when the surface of the part reaches the M_s point, transformation of austenite begins, and progresses to completion at the M_f point. It is readily seen that in water quenching of the part in question the outside is completely transformed while there is a large portion of the center still austenitic and above the M_s temperature; in other words, there is a large volume of unstable austenite entrapped in a case of hard, brittle martensite. Later, as the center cools through the martensite transformation range, the entrapped austenite transforms.

This would not be serious but for the fact that in the transformation of austenite to martensite there is an increase in volume. It is this internal expansion within a shrunk hard case

Fig. 5 — Numerous Microcracks — 15 in a Single Small Field — in Rapidly Quenched Carburized Case. Magnified 1000 diameters. (Shepherd)

that causes excessive residual strains and quench cracks, distortion and low ductility.

The curves for oil quenching show a slower rate of cooling and a smaller temperature difference between the outside and center of the piece, resulting in greater amount of transformation and accompanying expansion of the center before the surface reaches the M_F point and forms a case of brittle martensite. Oil quenching therefore results in a smaller volume increase as there would be less transformation to take place within the part after the transformation is completed on the surface.

Steels that harden on such slow cooling as in still air are used for complicated dies and sections because they transform (as shown by the curves in Fig. 6) at the same time in all parts, and thus have a minimum of residual strains and possibility of quench cracks. When air quenched, the temperature difference between the outside and center is quite small and the formation of martensite will occur as the temperature drops through the transformation range at a fairly uniform rate throughout the matrix of austenite. Furthermore there is usually a sizable amount of retained austenite at the end of the quench and this relatively soft constituent will cushion or adjust the stresses so that a minimum of residual internal strains result.

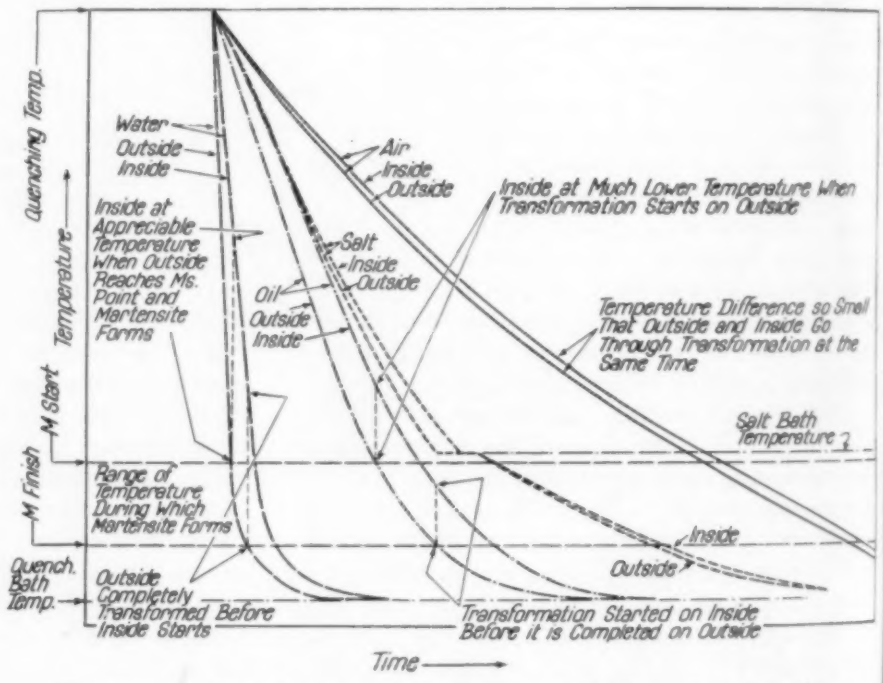


Fig. 6 — Cooling Curves at Surface and Center of a Certain Steel Cylinder When Quenched in Water, Oil, Hot Salt and Air

Martempering (as presented by B. F. Shepherd, past-president ASM, in articles in *Iron Age*, January 28 and February 4, 1943, and which by its name indicates that the formation of martensite is the prime objective) consists of quenching the hot steel in a liquid salt bath at an elevated temperature above the M_S point, holding in the bath long enough for the part to become uniform in temperature throughout, then cooling in air, then following with a conventional tempering operation if needed. This method of interrupted quenching produces martensite with very low residual strains.

Martempering thus includes the quenching from an austenizing temperature into a salt bath at a temperature near the M_S point of the steel and holding in that bath long enough for the center as the piece goes through the martensite temperature, then further cooling in the atmosphere at a moderate rate so as to set up no great temperature differential between the outside and center, as the piece goes through the martensite transformation range. Formation of martensite then occurs at a fairly uniform rate at innumerable locations throughout the matrix of softer austenite. An excess of residual strain is avoided by this equalizing process.

As noted, the temperature of the quench bath should be near the M_S point; if much below this temperature, an appreciable quantity of martensite will form and may defeat the purpose of the process. This M_S point varies with different steels, and can be computed by the formula given on page 733, but 400° F. has usually been found satisfactory for martempering the more tender of the S.A.E. alloy steels and the high carbon, low alloy toolsteels.

The operation is quite practical commercially, as the pieces may be held in the salt for considerable periods after equalizing in temperature with no effect upon the results. The S-curves show that austenite does not begin to transform for a sizable fraction of an hour when held steady at a temperature of 400° F.

The cooling power of salt at elevated temperatures had been previously underestimated.

but agitated salt at 400° F. is now established as having a quenching speed approximately as fast as the customary oil quench. This conclusion could be drawn from some figures published by the Germans, Lueg and Pomp, in *Stahl und Eisen* in 1941, p. 266, who measured cooling rates of ½-in. steel balls quenched from 1475° F. into oil at room temperature and salt baths at various temperatures. Cooling speeds at 1000° F. (the approximate nose of the S-curve) are:

Mineral oil at 70° F.	100 to 145° F. per sec.
Rapeseed oil at 70° F.	175° F. per sec.
Molten salt at 400° F.	115° F. per sec.
Molten salt at 500° F.	95° F. per sec.

Agitating the molten salt will bring the cooling power up to equal that of still mineral oil at room temperature, and quite high enough to quench many alloy steels to a 100% austenitic structure.

Stated in another way, the quenching speed of agitated salt at 400° F. has an "H value" of 0.25 to 0.30 (equivalent to still oil) on parts that have a machined surface. With materials having a light scale, the quenching speed is somewhat lower, approximately H = 0.20, equivalent to warm oil (see *Metal Progress Data Sheet* No. 29).

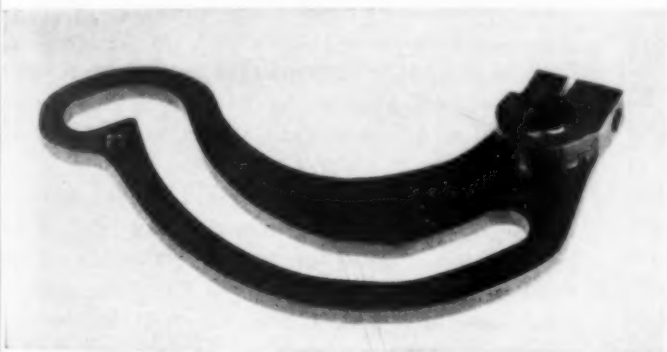


Fig. 7 — Slotted Cam, Finish Machined and Then Martempered to Preserve Dimensional Tolerances

Heavier sections can be hardened by the martempering process than can be handled by austempering, and with a very minimum of residual strains. The quenching speed of the bath should not be overlooked; obviously, the lower the temperature of the salt bath, the faster is its quenching speed.

The martempering method has been used commercially to improve the quality and production of a large number of products. A few examples are cited below:

1. Small hand chisels made of carbon steel, and alloy chisels for pneumatic hammers. Martempering eliminated quench cracks and produced greater hardness without spalling of the edges.

2. Alloy gears, to obtain high hardness with a minimum of distortion and dimensional changes with greater fatigue life.

3. Spring steels hardened with a minimum of distortion. Spring-steel products such as springs or knife blades have been martempered to high hardness and then tempered to the same physicals as austempered parts with better "resilience", in that they take less set in a flexing test.

4. Miscellaneous parts which must be finished, machined and then heat treated to high hardness, requiring a minimum of distortion and finished surfaces free from oxidation.

As an example, the slotted cam shown in Fig. 7 was machined from an annealed forging, then carburized to a case 0.012 to 0.016 in. deep, box cooled, reheated to 1500° F., quenched in salt at 400° F., and air cooled. Hardness is Rockwell C-60 min. The slot would close in when quenched in oil and had to be finish ground to the proper contour, requiring 3½ to 4 hr. By martempering, the contour is held to a minimum of distortion within allowable tolerances, and requires only a few minutes to buff the wearing surface.

Austempering

Austempering is an interrupted quench which consists of quenching steel in a molten bath — usually salt — maintained at a constant temperature at some point between 400 and 800° F. (usually toward the upper level of this range, which reduces the time required for transformation). The austenite transforms isothermally into bainite or intermediate structure. This process is used to attain hardnesses of C-48 to 55, along with added desirable characteristics of toughness and ductility. Commercially it is applied to heat treat wire, chisels, small springs, steel safety shoe toes, among many other applications which might be mentioned.

The accompanying table (page 738) shows the austempered hardness ceilings and suggested maximum austemperable size for various carbon and alloy steels, as recommended by the American Steel & Wire Co., a subsidiary of U. S. Steel Corp. which owns the patent.

Isothermal Quenching

A development in the interrupted quench is the "isothermal quench" described by Harold J. Babcock of Ajax Electric Co. in *Iron Age*, February 3 and 10, 1944. This method is a three-step process: *(a)* Heating to austenize, *(b)* immediately quenching in an agitated, heated salt bath

Hardness Limits and Commercial Maxima in Size for Austempered Parts

Type of Steel	Analysis of Steel					Hardness Ceiling, Rockwell C Scale	Largest Round (or Equivalent in Area)
	C	Mn	Cr	Ni	Mo		
Carbon	0.95 to 1.05	0.30 to 0.50				57 to 60	0.148 in.
Carbon (high Mn)	0.95 to 1.05	0.60 to 0.90				57 to 60	0.187
Carbon	0.80 to 0.90	0.30 to 0.50				55 to 58	0.156
Carbon (high Mn)	0.80 to 0.90	0.60 to 0.90				55 to 58	0.218
Carbon	0.60 to 0.70	0.60 to 0.90				52 to 55	0.187
Carbon (high Mn)	0.60 to 0.70	0.90 to 1.20				53 to 56	0.281
Carbon (very high Mn)	0.60 to 0.70	1.60 to 2.00				53 to 56	0.625
Alloy (C-Co)	0.65 to 0.75	0.75 to 0.95				53 to 56	0.625
Alloy (C-Cr)	1.00	0.40 to 0.60	0.40 to 0.60		0.25	57 to 60	0.312
Alloy (S.A.E. 4150)	0.45 to 0.55	0.60 to 0.90	0.80 to 1.10		0.15 to 0.25	52	0.500
Alloy (S.A.E. 5365)	0.60 to 0.70	0.50 to 0.80	0.50 to 0.80	1.50 to 2.00	0.30 to 0.40	54	1.0 or larger

at 450° F. or above and holding at this temperature to permit isothermal transformation, *(c)* immersing in a third bath maintained at a higher temperature that serves as a draw. This method allows isothermal transformation at a low temperature to produce high hardness, and then draws back to the required physical properties. In this manner parts of heavier section can be heat treated than can be handled in the conventional austempering method.

For example, if the latter method should be used for heat treating the M-66 fuse made of S.A.E. 4140, it would require a salt bath at approximately 800° F. Tests have shown that such a quench does not cool at a sufficient rate to get by the nose of the S-curve, and the product has a mixed microstructure of low yield strength, elongation and reduction of area. On the other hand Babcock's isothermal quenching in an agitated low temperature salt corrects these defects. This procedure is being used on shell component parts, aircraft engine parts and machine gun parts, to cite a few examples.

Specifically, the successful heat treatment of the M-66 fuses (handled in loads, 24 to a rack) consists of the following four steps:

1. Preheating in a gas fired furnace which burns off oil from the machined parts and saves time in the first bath.

2. Heating to austenizing temperature (1550° F.) in neutral salt; time: 12 min.

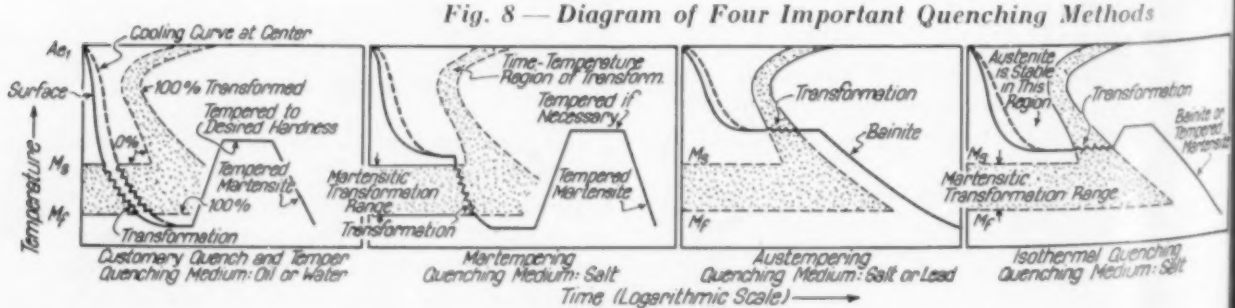
3. Quenching in salt at approximately 550° F. for 12 min. to permit isothermal transformation. The quench tank salt is agitated by motor driven propeller. Absorbed heat is dissipated by forced air circulating through a welded steel jacket around the salt quench tank.

4. Fuses are transferred to a tempering bath of the same composition as the quench salt, maintained at 800 to 850° F. Fuses when removed are allowed to drain and are cooled slowly in air.

One plant heat treats over 250,000 fuses each month in this manner without any rejections due to cracking, distortion or low physicals. Fuses with heavier sections, made of the same grade of steel, are now being heat treated the same as above except a longer time cycle is required to heat and quench this heavier section.

In summary, the various modern types of interrupted quenches designed to eliminate or materially reduce quench cracks, distortion and dimensional changes, include martempering, austempering, and isothermal quenching. The mechanics of each method are diagrammed in Fig. 8. In all of them duplication of results is possible by workmen who are comparatively new to the science of heat treating.

Fig. 8 — Diagram of Four Important Quenching Methods



Casting Technique for Lead Base Babbitt Alloys

By R. G. Thompson
Schenectady Works Laboratory
General Electric Co.

WHEN TIN WAS READILY AVAILABLE it was customary to use a composition of 83⅓% tin and 8⅓% each of copper and antimony for babbitt. Metallurgists hardly need to be told that tin today is among the scarcest of the metals, and that babbitt may no longer contain as much tin as formerly. The War Production Board's tin conservation order limits the tin content of babbitt to 12%, except for implements of war, wherein the conventional high tin babbitts are permitted unless a lower tin content is acceptable to the specifying agency.

General Electric has gone far beyond the W.P.B. restrictions on use of tin. Thus, for instance, its commonly used babbitt now contains only 1% tin. It is a lead base alloy, composed of 82.5% lead, 15% antimony, 1% tin, 1% arsenic, and 0.5% copper. This composition is identified as F23 babbitt (Cleveland Graphite Bronze Co.), or Boveall babbitt (Federated Metals Co.). Possibly "babbitt" is the wrong term to use except in the sense of "material to line bearings".

Extreme tests made in G. E. laboratories and engineering divisions preceded its adoption. It is now being used widely on motors and other apparatus with rotating members. Although not well adapted for turbine bearings, a number of lead base bearings have been installed in steam turbines and are under careful observation. Also one large thrust bearing for a 60,000-kva. generator has been installed at Bonneville power house on the Columbia River. No changes in bearing design were necessary, and the lead base bearings carry the same unit loads or pressures as did the tin base bearings.

Microstructure (100 Diameters) of Bearing Metal Containing 1% Tin in a Still-Cast Thrust Plate. Eutectic is antimony-lead; white crystals are excess antimony or antimony-rich compounds

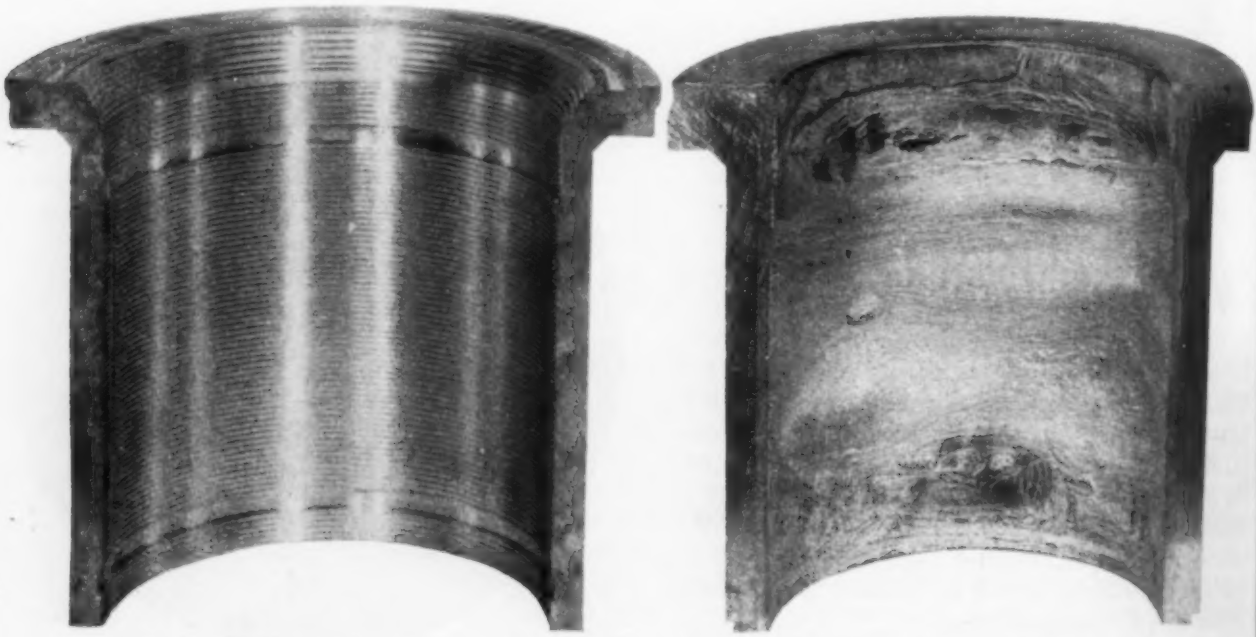
In the lead base alloy, approximately 12% of the antimony combines with the lead to form a eutectic mixture, and the balance of the antimony separates out as hard antimony-rich compounds. The photomicrograph at the head of this column shows the typical structure of this material at 100 diameters.

Arsenic is incorporated in this alloy chiefly to raise its annealing temperature. Tin primarily assists in obtaining a good bond between the babbitt and the shell, and it also probably serves in some manner to prevent oil corrosion.

Because of the marked difference in density

between the antimony-rich phase and the heavier lead-antimony eutectic, there is a marked tendency for these two phases to separate, resulting in regions containing only the eutectic phase with little or no hard antimony compound, and with other regions containing excessive amounts of antimony-rich compound. Therefore, considerable testing and experimenting have been necessary to establish proper casting technique and reduce this segregation to a minimum.

From a design standpoint, there are two general types of bearings: *(a)* Bonded type, where the babbitt is alloyed to the bearing shell or liner; and *(b)* unbonded type, where the babbitt is held in the bearing shell by means of dovetail anchor grooves. Each of these two types can be either centrifugally cast or still cast.



Split Bearing Lining for a 6½-In. Shaft. At left is the bronze liner, grooved for anchoring babbitt. Grooves are 0.025 in. deep, 0.050 in. wide, spaced 0.100 in. on centers. View at right shows as-cast condition of centrifugal-cast lead base babbitt

The casting characteristics of the lead base babbitt differ from the tin base babbitt, and the establishment of correct casting procedure is the most important part in the production of good bearings. A perfectly good babbitt alloy can be ruined by improper or careless casting procedure.

It is difficult to outline the exact details which would be applicable for all bearings. However, some general rules can be outlined:

Centrifugally Cast Bearings

Centrifugal casting procedure may be summarized as follows:

1. The bearing shell must be sprayed with water, or water and air, immediately after the babbitt has been poured into the shell or liner, to cool the metal as rapidly as possible.

2. For a bonded type bearing, the shell is first degreased, pickled, fluxed, and pre-coated by immersing it in a suitable bonding alloy at temperatures ranging from 575 to 625° F. The pre-coated shell is then removed from the bonding alloy pot and immediately placed in the centrifugal casting machine, while the bonding alloy coating is liquid and clean.

3. It has been found that the thickness of the bearing shell should not be more than ½ in. if segregation is to be prevented. With heavier shells, the heat cannot be extracted fast enough to solidify the babbitt before segregation occurs, and hard, antimony-rich compounds are thrown toward the inside, leaving only the softer lead-antimony eutectic phase next to the shell. The degree to which this takes place depends upon the rate of cooling and the centrifugal speed at which the shell is rotated.

4. The spinning should be as slow as possible, and yet throw the babbitt out against the bearing shell. The higher the speed, the greater the centrifugal force causing separation of the two phases of different density.

5. For unbonded bearings, it can be assumed that heavier or thicker shells can be centrifugally cast without segregation, since it is necessary only to preheat such bearings to 250° F. (in order to drive off any moisture). Therefore,

with less heat to extract from the shell and with adequate water cooling, it should be possible to solidify the babbitt before segregation occurs. Very little work has been done with this type of bearing and, therefore, the above opinion has not been fully established.

6. Babbitt of this composition is poured from 850 to 925° F.

Still or Stationary Cast Bearings

For unbonded bearings, the following procedure has been established: *(a)* Preheat shell to 225° F. *(b)* Preheat mandrel to 600° F. *(c)* Pour babbitt at 775 to 800° F. *(d)* Water-cool bearing shell immediately after the babbitt has been cast.

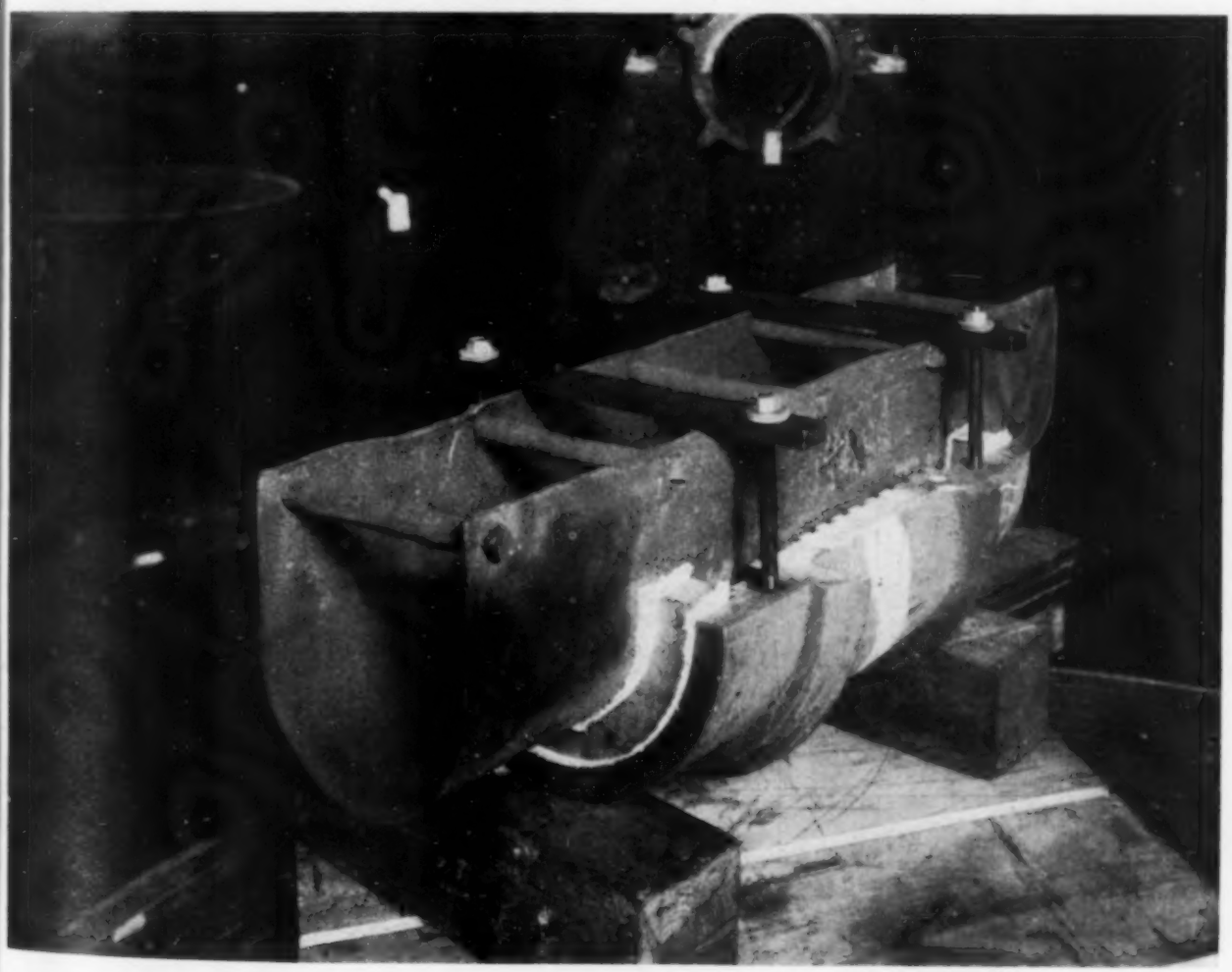
With the above temperature gradients, the babbitt freezes from the shell toward the mandrel, resulting in a close bond to the bearing shell.

The bearing and mandrel can be set up either horizontally, as shown in the engraving, or vertically. Usually, when the length of the bearing is greater than the inside diameter, it is preferable to cast the babbitt with the shell in a horizontal position. Most bearings of this type are made with a cast iron shell, and are usually the ball seat design.

Bonded, still cast bearings have not been produced in any large quantities. However, enough work has been done in still casting the bonded-type bearing to prove that it has some advantages over the centrifugally cast method. The one marked advantage is that there is no centrifugal force causing segregation of the two phases. Therefore, the babbitt does not have to be chilled as quickly, and bearing shells with thicker walls can be cast free from segregation.

The bearing shell is cleaned and coated with the bonding alloy, the same as for centrifugally cast bonded bearings, and the shells are set in the casting jig while the coating is liquid and clean. The casting jig is preheated to a temperature of about 500° F., and the babbitt poured.

14-In. Diameter Cast Iron Bearing Shell Set up With Mandrel in Place Ready for Pouring of Bearing Alloy



The shell is water-cooled as rapidly as possible with a water spray after pouring is finished.

Bonding Quality of Lead Babbitt

Lead babbitt bonds very well to steel shells — in fact, more reliable bonds are obtained with this babbitt than with the old fashioned tin babbitt. The type of bonding alloy used for steel shells is not critical. All of the following alloys have been used successfully:

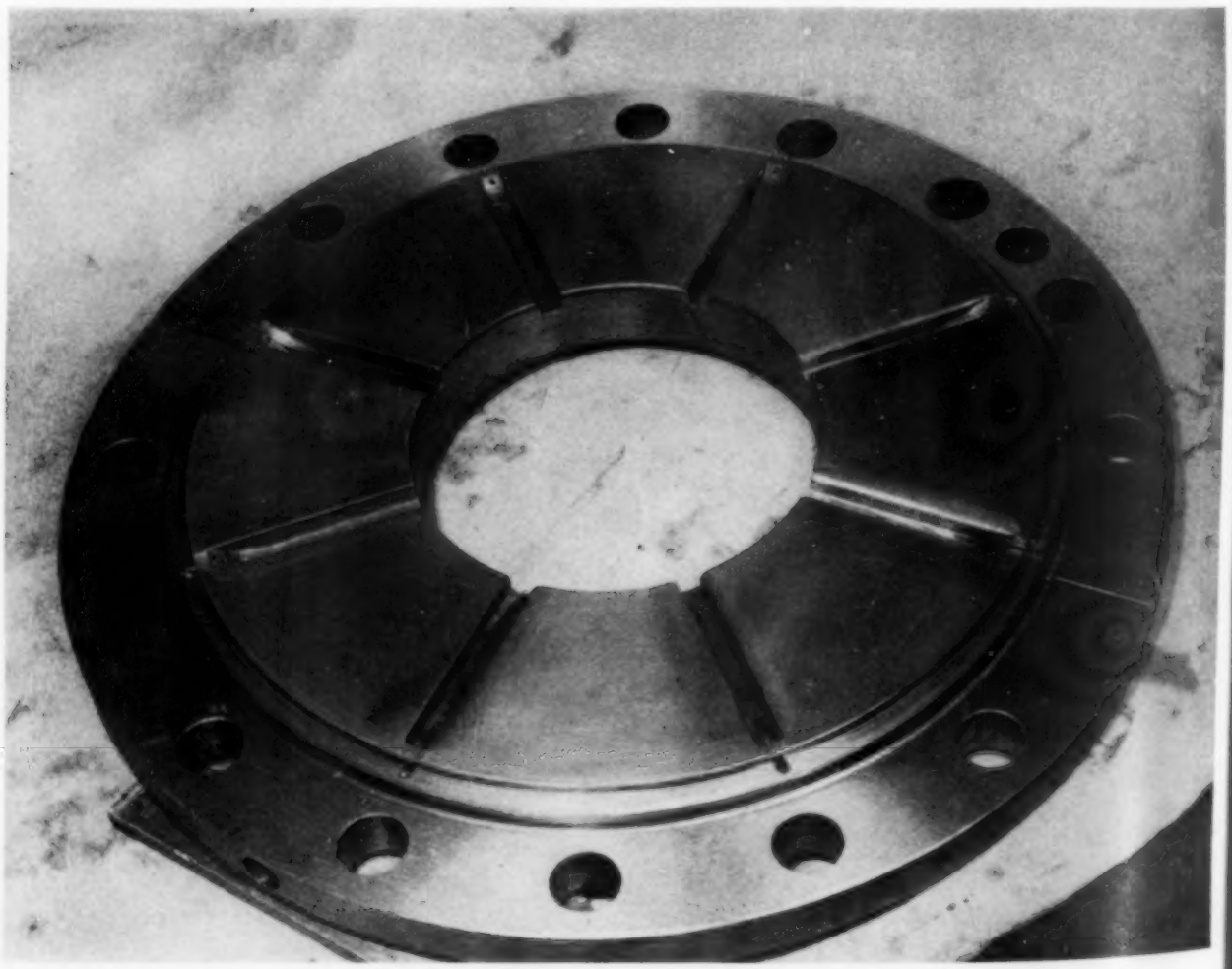
Alloy A: 5% tin, 5% antimony, 90% lead.
Alloy B: 10% tin, 10% antimony, 80% lead.
Alloy C: 30% tin, 70% lead.
Alloy D: 20% tin, 1.25% silver, 78.75% lead.

Bonding of lead babbitt to bronze shells has not been as successful as to steel shells. The best bonds for bronze are with Alloy D. Bonding alloys containing antimony are particularly unsatisfactory. It is necessary to machine radial grooves approximately 0.05 in. wide by 0.02 in. deep, approximately 0.1 in. apart in the shell surface, to obtain some mechanical anchorage on the bronze shells. Also the temperature at which bonding occurs is important; the bonding alloy should be just above its melting point — higher temperatures result in poor bonds.

Oil Corrosion

Laboratory tests indicate that lead base bearings are attacked at temperatures of the order of 180° F. and above by oils having a neutralization number higher than 1.0. (Neutralization number is the number of milligrams of caustic potash required to neutralize the acid in 1 g. of oil.) The lead base bearing alloy described does not appear to accelerate the oxidation rate of the oil to any appreciable extent, but if the oil becomes oxidized for other reasons and the neutralization number goes above 1.0, then the oil will corrode the bearing.

Tapered Land Thrust Bearing Plate for 1500-Kw., 3600-Rpm. Steam Turbine 12 In. Outside Diameter by 5½ In. Inside Diameter. Still cast of lead base babbitt



Double Temper Mo-W High Speed at Slow Heating Rate

By K. J. Trigger
Ass't. Prof. of Mechanical Engineering
University of Illinois
Urbana

DURING AN INVESTIGATION on the transverse strength and toughness of molybdenum-tungsten high speed steel, it became advisable to evaluate the effect of the heating rate in tempering. Tests were also conducted to determine the effectiveness of a double temper on the transverse strength of small test beams.

This investigation was carried out on high speed steel containing approximately 5½% tungsten, 5% molybdenum, 4% chromium, 1½% vanadium, and 0.8% carbon. Material was secured through the kindness of Columbia Tool Steel Co. Test samples were prepared from commercial ½-in. square stock cut into lengths of about 4½ in. They were shaped equally on all sides to approximately 0.4-in. square, and surface ground to 0.385-in. square prior to heat treatment.

The heat treatment consisted of *(a)* preheat at 1100° F. for 15 min., *(b)* preheat at 1500° F. for 15 min., *(c)* high heat at 2230 ± 5° F. for 4 min., *(d)* quench in oil at 80° F. until cold, and finally *(e)* temper as follows:

1. Place in an unheated electric furnace, heat to 1025° F. in 1½ hr., hold 1 hr., and air cool. Repeat operation starting with a cold furnace, hold 1 hr. at 1025° F., and furnace cool.

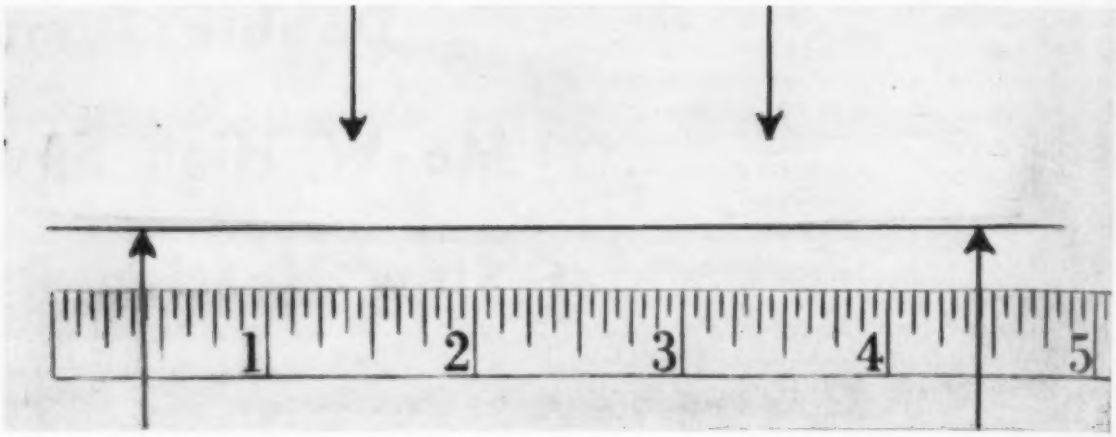
2. Place in a hot electric furnace and heat to 1025° F. in 10 min., hold 1 hr., and air cool. Repeat operation, hold 1 hr. at 1025° F., and furnace cool.

3. Single temper, starting with a cold furnace; heat to 1025° F. in 1½ hr., hold 2 hr., and furnace cool.

After tempering, the specimens were carefully surface ground to approximately 0.375-in.

Results of Bending Tests on High Speed Steel

Test	Modulus of Rupture	Rockwell Hardness	Deviation from Average	Deviation, % of Average
Double Temper — Slow Heating				
1, unbroken	542,500 psi.	C-65.9	+4900 psi.	Over +0.91
2	533,500	65.6	−4100	−0.76
3, unbroken	540,500	65.4	+2900	Over +0.54
4	534,000	65.9	−3600	−0.67
	Average: 537,600+			
Double Temper — Fast Heating				
1	503,000 psi.	C-65.9	+3200 psi.	+0.6
2	482,000	65.9	−17,800	−3.6
3	478,000	65.5	−21,800	−4.4
4	538,000	65.8	+38,300	+7.6
	Average: 499,800			
Single Temper — Slow Heating				
1	401,000 psi.	C-65.5	−53,000 psi.	−11.68
2	469,500	65.3	+15,500	+3.41
3	463,500	65.5	+9500	+2.09
4	482,000	65.5	+28,000	+6.16
	Average: 454,000			
Untempered	85,000 psi.			



One of the Specimens (Double Tempered With Slow Heating) Which Did Not Break When the Load Reached the Testing Machine's Capacity. Hardness C-65.9; extreme fiber stress 542,500 psi., permanent deflection about 0.050 in. on 4-in. span

square. An open structure wheel, frequently diamond dressed to insure free and cool cutting conditions, was used. At no time during the grinding did the specimen feel uncomfortably warm to the touch.

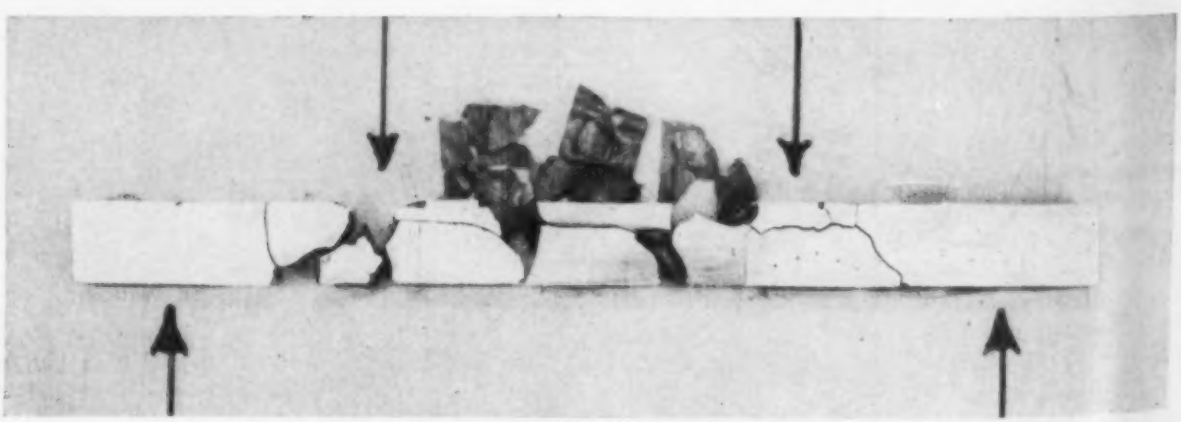
The ground specimens were then tested in a fixture designed to provide a constant bending moment over the middle 2 in. of a 4-in. test span. A hand operated testing machine was used to load the specimens, the loading rate being from 600 to 700 lb. per min. until (and if) failure occurred. Since the capacity of the machine was only 12,800 lb., two specimens were not broken.

The calculated modulus of rupture takes into account all errors introduced by roll on the supports and loading points. The modulus of elasticity as calculated from the deflection data (in the elastic region of the test) ranged from 29,500,000 to 30,500,000 psi., a very satisfactory check. The results of the different tempering treatments are shown in the table on page 743.

Fast heating, as the term is herein interpreted, consisted of an average heating rate of about 90° F. per min., though the maximum rate was 240° F. per min. in the range of 100 to 600° F. — the range in which the hardened specimen can least readily accommodate the volumetric changes brought about by heating. Slow heating consisted of an average rate of 10° F. per min. with 20° F. per min. the fastest.

The desirability of slow heating for tempering is borne out by the results, although the increase in bending properties due to slow heating is comparatively unimportant under the test conditions. A survey of the results of slow vs. fast heating reveals that slow heating is superior with regard to both average strength and consistency of results. The total variation (maximum to minimum) of the slow heated samples was somewhat over 9000 psi. whereas the fast heated test beams revealed a total variation of about 60,000 psi.

A comparison of single and double tempering, both under slow heating conditions, shows



A Specimen, Also Double Tempered With Slow Heating, That Broke at 533,500-Psi. Extreme Fiber Stress. Hardness C-65.6

that a definite benefit accrues when double tempering is used. The average strength is some 84,000 psi. higher, and the total variation is but 9000 psi. as compared to some 81,000 psi. for the single tempered samples. The improvement is definite though not as pronounced as may have been expected.

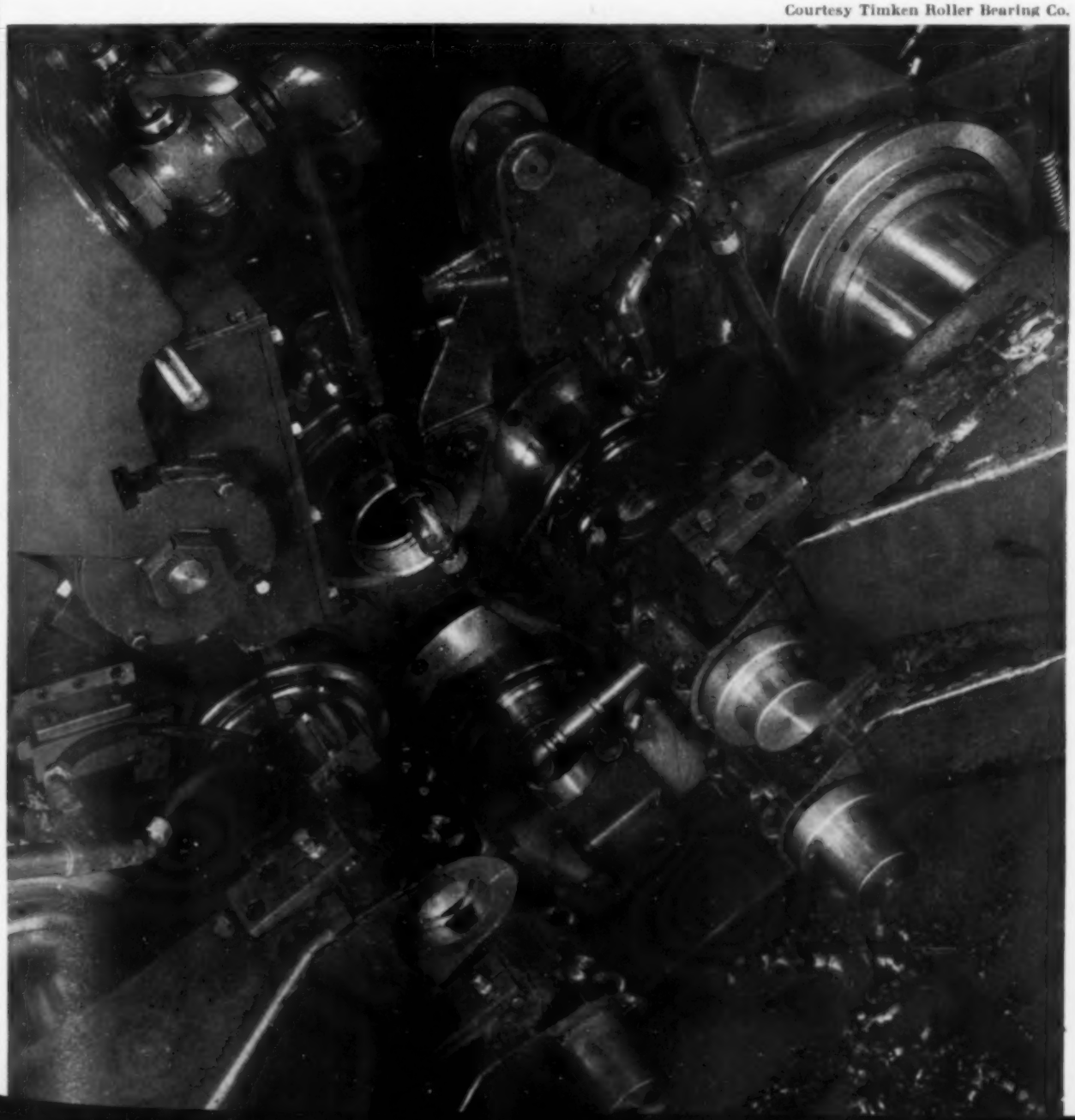
The writer believes, on the basis of magnetic study, that the transformation of retained austenite in this steel, on cooling from tempering, occurs in the range of 500° to 550° F., and transformation in such a range permits appreciable stress relief in the martensite so formed. Of course, volumetric changes brought about by this transformation may still affect the remaining material and cause weakening due to very small cracks.

The benefits of double tempering would, of course, be much more pronounced on irregularly sectioned tools and dies. Spalling at sharp sectional changes ought to be much less when such tools are double tempered.

As a matter of curiosity one test bar was hardened, ground, and tested without any tempering whatever. The modulus of rupture obtained on this bar was approximately 85,000 psi., indicating the folly of using untempered high speed steel.

The accompanying photographs show two tested beams. One specimen did not break at an extreme fiber stress of 542,500 psi. Yielding began at a stress of about 400,000 psi. and progressed gradually. The maximum deflection under load amounted to nearly ¼ in. with 0.050 in. of permanent set remaining after the load was released. The other beam failed at an extreme fiber stress of 533,500 psi. Note the fragmentation of the section which was subjected to a constant bending moment; the specimen virtually exploded at failure.

Courtesy Timken Roller Bearing Co.



Correspondence

Letters of Interest from Home and Abroad

"Fibering" in Acid Openhearth Steel

NICETOWN, PHILADELPHIA, PA.

To the Readers of METAL PROGRESS:

I think I recognize many of my own statements in the portion of p. 482, of September's *Metal Progress,* dealing with acid openhearth steel, since I discoursed briefly on the quality of acid steel at the round table being reported. I therefore agree with practically everything. I disagree, however, with the statement that "acid steel 'fibers' more readily than basic openhearth steel". Our experience at Midvale is to the contrary, though I don't mean to argue that it should be accepted as a proven fact. In heavy armor, where "fiber" is generally conceded to be a prime requisite, I believe the British still use acid openhearth whereas we, in this country, prefer basic steel. I know of no evidence to support the statement that acid steel is the more readily fibered and would be interested in learning what evidence, if any, exists.

FRANCIS B. FOLEY
Superintendent of Research Dept.
The Midvale Company

Zinc Widely Used in War-Time France

SOMEWHERE IN FRANCE

To the Readers of METAL PROGRESS:

Prior to the war, the principal metals used by industry in France (as in other civilized countries) were iron, copper and nickel, aluminum, zinc and lead. Following the German invasion the industrial use of the imported metals copper and nickel was prohibited. Although the two light metals are of European origin, almost all of the supply was preempted for war materiel. Civilian supply, such as it was, had to content itself with salvaged scrap, and the substitution of the only metals available, even of limited supply — namely, iron, lead and zinc.

In contrast with what happened during the historic evolution of the uses of metals, substitution had to take place quickly, without trials and errors, or prolonged tests. Fortunately — in the case of zinc, at least — scientific study had progressed so that the proper limits of fields of application could be the more readily set.

For zinc, three unique characteristics govern — as is well known:

(a) It is very fusible, melting at 787° F. This makes it an excellent metal for the foundry, especially when alloyed with a little aluminum. On the other hand, it recrystallizes and deforms plastically at a low temperature; hence zinc parts cannot be expected to carry loads at temperature much above atmospheric.

(b) Zinc crystallizes in the hexagonal close packed system, and only three metals (copper, aluminum and silver) have a large solubility in it. Each of these solubilities decreases with temperature, and so there is a possibility of "precipitation hardening", but this turns out to be limited. Precipitation in many zinc alloys has been proven to be harmful rather than helpful, because of the appearance of the associated corrosion cracking. This leads us to the third noteworthy characteristic of zinc:

(c) Zinc is electro-negative and easily attacked by acids. Unless great care is given to the purity and composition of the alloys they are even unstable in size and unreliable in moist, warm localities. Unfortunately, when much of the supply is had from scrap, purity cannot readily be achieved.

Despite all these handicaps, inherent on the one hand, and due to the misfortunes of war on the other, zinc has been of considerable use in meeting some essential needs of our civilians. Success has been achieved largely through the application of information developed and published by the American firm, New Jersey Zinc Co.

The uses in pressure casting have been very numerous, producing pieces of complicated shapes, which do not need to be machined — therefore they are spreading in varied industries. In many cases the zinc alloys can take the place of copper alloys, especially the brasses. Very interesting results have been obtained as antifriction metals for ball bearings, which may be an application appearing strange to Americans. Its

uses in plumbing for cold water systems are being developed. In electricity, zinc wires are being tested as conductors; for this purpose pure zinc with 0.15% iron has a creep strength of 2700 psi. (0.2% elongation at room temperature in 15,000 hr.), ten times the value of the 1% Al, 0.5% Cu alloy previously used in Germany.

But it is important to state that it is to the careful scientific study of these properties and phenomena that we are indebted for the possibilities of using alloys of high zinc content. They have thus been freed of the justified discredit caused by disappointments and defects arising during their first applications more than 20 years ago.

ALBERT PORTEVIN
Bessemer Medalist

Supposed Graphite in Carburized Steels

EDITOR'S NOTE — In *Metal Progress* for June 1943 Messrs. WELCHNER and ROUSH presented a most valuable study of the above subject, then of sudden importance because of the discovery of a grain boundary constituent very close to the surface of carburized articles of NE steels, and the snap assumption made by some metallurgists that it was an inherent drawback to the use of these triple-alloy steels. Welchner and Roush attacked the problem directly and got a quick answer; they could not be expected to make an exhaustive study of the literature.

M. RIDDIHOUGH, technical manager for Deloro Smelting & Refining Co., Ltd. of Birmingham, England, writes that a similar accumulation of "scale or oxide" at the grain boundaries was noted by him when studying the decarburized surface of heat treated leaf springs (silico-manganese steel), and published in *Journal* of the Iron & Steel Institute, 1931 (II), page 445, as a discussion to an article by Hankins and Becker on "The Effect of Surface Conditions Produced by Heat Treatment on the Fatigue Resistance of Spring Steels". This discussion dwelt primarily with the penetration of a hardening constituent along the grain boundaries to at least twice the depth below the surface. This hardened ferrite is shown by polishing on selvyt cloth after ordinary etching, and the "abnormal" boundaries stand in relief — an effect noted by Stead in the same *Journal* as early as 1921. The evidence presented by Mr. Riddihough in 1931 led him to state that the "abnormal ferrite" bounding each ferrite grain "might be a solid solution of oxygen or iron oxide in iron".

From another source, the Editor also learned that MARY BAEYERTZ, in some "Observations on the Oxidation of Steel" (*Transactions* ASM, June 1936, p. 420) presented many micros showing silicate particles at grain boundaries and ferrous oxide within the grains of steels near the surface of samples heated in oxidizing atmospheres. Probably many other examples, even of earlier work, could be found if one were to search the metallurgical literature.

The point of this note is rather to call attention to the inference (if not the direct statement) in Welchner and Roush's article that the formation of silicates below the metal's surface was due to reaction with CO gas diffusing into the hot solid. The Editor also has retained for many years the recollection that in Federico Giolitti's classic "The Cementation of Iron and Steel" the mechanism is based on the equilibrium between Fe, Fe_3C, CO and CO_2, and hence presumably the gases diffuse into and out of the steel. (A recent scanning of the pages finds no place where Giolitti states, categorically, that such diffusion does actually occur.)

Now comes a series of notable articles in *Metal Progress* by FLOYD E. HARRIS, where he explains the gas carburizing mechanism as a metal-gas reaction liberating carbon *at the surface*, and the diffusion of carbon inward. In view of the great difficulty Petch and his English collaborators have in finding *(Continues on p. 748)*

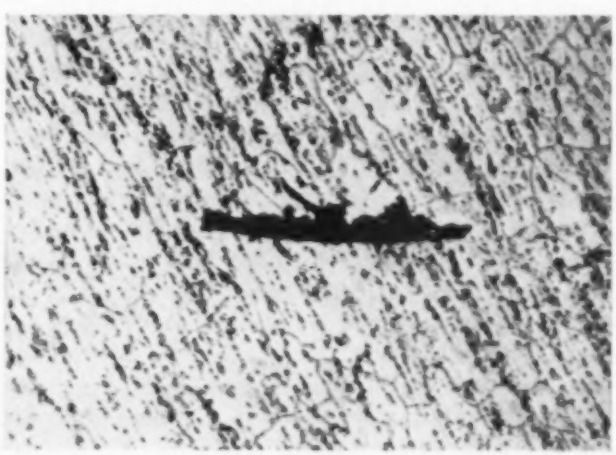
Ghostly Battleship

PATERSON, N. J.

To the Readers of METAL PROGRESS:

Here's a battleship cruising in the matrix of our forged piston alloy A.M.S.4140. Undoubtedly our Navy is seeking the Jap even here.

WILLIAM C. BANKS
Assistant Metallurgist, Materials Laboratory
Wood-Ridge Plant, Wright Aeronautical Corp.



Fleck of Dust With Formidable Shape

room for the carbon atom to tuck itself away in the iron lattice, the Editor asked some American authorities whether it is physically possible for a supposedly larger *molecule* like CO or CO_2 to get inside the iron lattice.

WHEELER P. DAVEY, research professor of physics and chemistry at Pennsylvania State College, writes: "Even the smallest dimension which can be assigned to CO and CO_2 would indicate that it is highly improbable that these gases could diffuse in steel with any reasonable speed. I believe it is pretty generally understood among X-ray crystallographers that when carbon diffuses in steel the actual transfer is a transfer of carbon. Diffusing carbon must be assumed to be constantly in combination with iron but the Fe_3C molecule as such does not travel. We must assume that the diffusing carbon merely loosens its chemical bonds with an Fe on one side and picks up chemical bonds with an Fe on the other side. In this way the carbon can migrate "hand over hand" like dancers in the square-dance figure "grand right-and-left". There is every reason to assume that the migration of oxygen in iron and steel is accomplished by a similar mechanism, so that although each individual atom of oxygen is at all times bound to neighboring iron atoms in the form of one or more of the oxides of iron, any given oxygen atom is not permanently tied up to any one iron atom. The same would be true of other elements that form "compounds" with iron. Diffusion of an inert atom (as argon through heated quartz) is said to follow a different law entirely and acts nearly like flow through minute orifices.

"From the standpoint of theory it can hardly be doubted that Harris's work on the penetration of carbon is correct."

ROBERT F. MEHL, director of Metals Research Laboratory, Carnegie Institute of Technology, also answered and commented on the Editor's proposal to explain the silicate films at grain boundaries by the preferential diffusion of oxygen at grain boundaries where it reacts with silicon atoms, and insoluble and immobile silica particles are built up there by reaction with more and more silicon atoms diffusing to the impoverished grain boundaries. On this basis the presence of *alumina* particles throughout the grains rather than at the boundaries would be explainable if aluminum had a considerably slower rate of diffusion than silicon in steel at 1700° F. Dr. Mehl writes:

"In scientific studies of carburization, as far as I know, it has never been assumed that CO and CO_2, as such, diffuse into steel. It is true that in carburization in CO both carbon and oxygen diffuse inward, but they diffuse independently and not as a molecule. Grain boundaries appear to play no part in carburization; the rate of diffusion of carbon is practically independent of grain size and carburization itself shows no grain size effect. However, the extensive work of my associate FREDERICK N. RHINES on internal oxidation of copper and some other non-ferrous alloys (presented before the Institute of Metals, A.I.M.E. since 1940) shows that oxygen diffuses at a higher rate along the boundaries than across the grain itself. This difference is small and frequently inappreciable at high temperatures, exhibiting itself more pronouncedly at relatively low temperatures. Results found by Messrs. Welchner and Roush are entirely explicable on the sound basis that carbon and oxygen diffuse into hot steel during pack carburizing, quite independently, each with its characteristic rate."

Finally, Mr. WELCHNER writes as follows, to close the discussion:

"In the experiments with grain boundary non-metallic precipitate during carburizing conducted by Mr. Roush and myself and published in *Metal Progress* in June 1943, we were not concerned with the *exact* mechanism of the reaction — that is, whether the CO or the oxygen itself was soluble in the hot steel. Our suggestion that nascent oxygen is the reactant is not refuted by admitting that atomic oxygen diffuses inward rather than the CO molecule.

"There is, of course, another possibility which must be considered in this connection; it depends upon the continuity of the oxidized silicon with the surface of the steel. It is not inconceivable that a limited oxygen solubility in the oxidized silicon (probably silicate phase) exists which would then be the vehicle for the oxygen to penetrate beyond the gas-solid interface. This concept would be strongly supported by the occurrence of the silicon-bearing nonmetallic in the grain boundary but does not appear to be valid for the oxidized aluminum phase as found in the nitralloy steel. The more or less random distribution of the oxidized aluminum (apparently not in the grain boundaries and not continuous) would indicate that either CO or oxygen had a certain solubility in austenite itself.

"Referring again to our experiments, they hardly were complete enough to reach an answer to the problem. Also while we could theorize at great length based on the information at hand, such deductions undoubtedly would have to be supported by X-ray work and diffusion experiments, which we were in no position to do."

Intergranular Surface Constituent in Malleable Iron

ROCKFORD, ILLINOIS

To the Readers of METAL PROGRESS:

Two recent articles by John Welchner and Roy W. Roush on "Supposed Graphite in Carburized Cases" (*Metal Progress* for June 1943 and March 1944) call attention to the presence of foreign material in the grain boundaries near the surfaces of carburized NE and S.A.E. steels.

The condition described is occasionally encountered also in malleable iron which has been annealed in periodic ovens. Whereas a penetration of 0.001 to 0.002 in. is given for steel, the depth of this intergranular constituent may be as high as 0.025 in. in malleable iron. (It is assumed that this greater penetration in malleable iron is due partly to the long time, approximately 48 hr., at the first stage graphitization temperature of 1600 to 1700°.

When this constituent is found in malleable iron, the depth seldom exceeds a few thousandths of an inch, and no harmful effects have been observed. However, when it occurs at considerably greater depths, it has a detrimental effect on both castings and test bars. The zone containing this constituent is quite brittle, and tends to spall off from heavy castings when they are milled. Test bars having such a surface condition may show low strengths and elongations, the decrease depending on thickness of the surface layer.

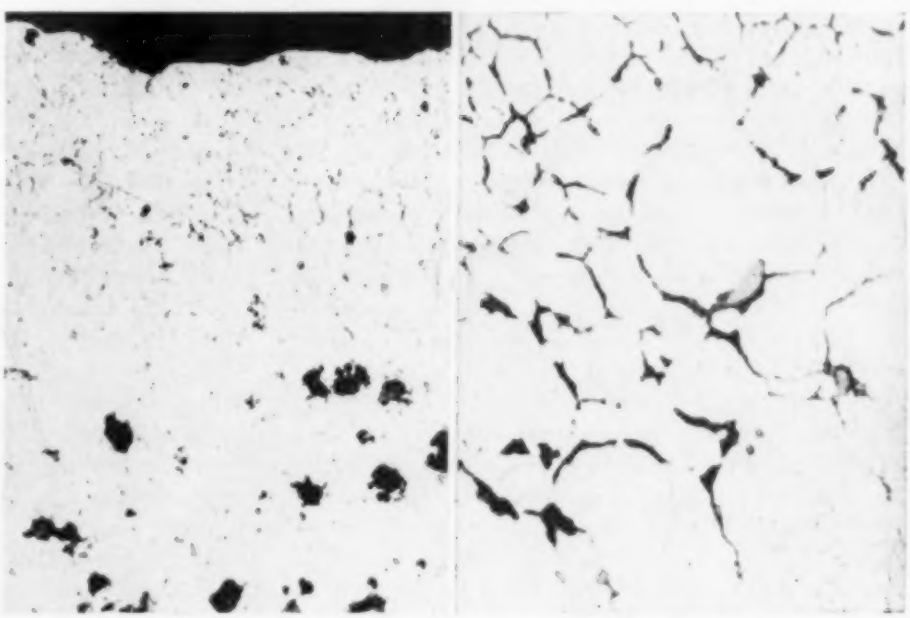
I enclose two micros taken from an annealed test bar. The first shows a penetration to approximately 0.012 in. The other, the center of which is at a point 0.008 in. below the surface, shows the intergranular constituent at higher magnification and in more detail. It is interesting to note the increase in grain size as the distance from the surface increases. Total carbon of this bar in the white iron state was 2.43% and the silicon content 1.00%. Normally this composition would give a tensile strength of about 54,000 psi. and elongation in 2 in. of about 18%, in a completely annealed test bar. Actually, the tensile strength was 47,800 psi. and the elongation 11%. Microscopic examination showed that the bar had been completely annealed, no free cementite or pearlite being present.

In conducting systematic etching tests according to procedure given in the Metals Handbook, the dark grain boundary constituent was not attacked until a 20% aqueous solution of hydrofluoric acid was used. (Messrs. Welchner and Roush obtained the same results in their tests.) The grain boundary constituent would seem to be a silicate, most probably an iron silicate.

This constituent is found in annealed malleable not only between the grains but also in globular form and all combinations of both types. Numerous white iron specimens have been examined, but no such constituent has been found in unannealed iron. This leaves only the packing material and the atmosphere during annealing as the possible sources of formation of the constituent. The latter is surely the more logical source; it would seem that packing material is a factor only as it affects the atmosphere immediately surrounding the work.

The above notes are intended only to show

Intergranular Surface Constituent in Annealed Malleable Iron



Edge of annealed malleable test bar. Depth of penetration of intergranular constituent is approximately 0.012 in. 100 diameters, unetched

Center of this view is 0.008 in. below edge. Note smaller grains toward edge (top of view) and presence of manganese sulphide inclusions (light gray). 500 diameters, unetched

the occasional existence of the intergranular constituent in malleable iron, and to point out that it is an undesirable condition. The exact nature of the reactions involved in its formation is not yet known, but their study would be an interesting and beneficial project.

EUGENE M. STEIN
Metallurgist
Gunite Foundries Corp.

Sigma Phase Brittleness in Heat Resisting Steels

SHEFFIELD, ENGLAND

To the Readers of METAL PROGRESS:

It is well known that the sigma phase can be formed in steels of high chromium content — with or without other alloying metals — over rather wide ranges of composition. It is also known that the sigma phase is very hard and brittle; its brittleness is, in fact, so pronounced that the behaviour of samples consisting wholly or mainly of it has been likened to glass rather than metal. Such material is hardly likely to receive much practical application, but there is in common use quite a number of high chromium-nickel "steels" — some of them containing also appreciable amounts of other alloys such as silicon, tungsten, molybdenum — which are essentially austenitic in character but contain a certain proportion of ferrite in their structure after they have been softened in the normal way at 1900° F. or thereabouts. In many of these alloys the more ductile ferrite changes partly or wholly to the more brittle sigma phase if they are heated for longer or shorter periods between 1100 and 1550° F. (and even below 1100° F. if the heating is sufficiently prolonged) resulting in considerable loss of toughness, particularly in notched tests. Examples have been published in Britain of the Izod impact values being reduced in this manner from 60 ft-lb. or so to 5 ft-lb. or even less.

So far as I am aware, however, all such published data have referred to tests carried out on the steel after it has cooled down to atmospheric temperature. Is the hot steel equally brittle?

Obviously this is important, because if the steel is being used under conditions involving more or less continuous exposure at a dull red heat, the production of the sigma phase will cause less trouble if the steel still retains its toughness while hot, and becomes brittle only when it has cooled to atmospheric temperature. There is actually some evidence that toughness and ductility are reduced while the steel is still hot. Thus Bruhl, in his early investigations on chromium-manganese steels, found that those containing 30% chromium and 15% manganese readily transformed, at a red heat, almost entirely to the sigma phase and that, if this occurred, the steels became quite unforgeable.

I met a case a few years ago where one of these normally tough, duplex steels became brittle and fractured in use, owing to the formation of the sigma phase under conditions involving continuous heating for a long period at 850 to 925° F. Other examples have been noted which point in the same direction.

The following experiments were, therefore, carried out in Sheffield to obtain more precise data regarding the properties of such sigma-containing steels while hot:

Bars of two austenitic steels containing

STEEL	C	Si	Cr	Ni	W
A	0.37	1.77	20.7	7.0	3.54
B	0.32	1.41	21.4	10.2	3.45

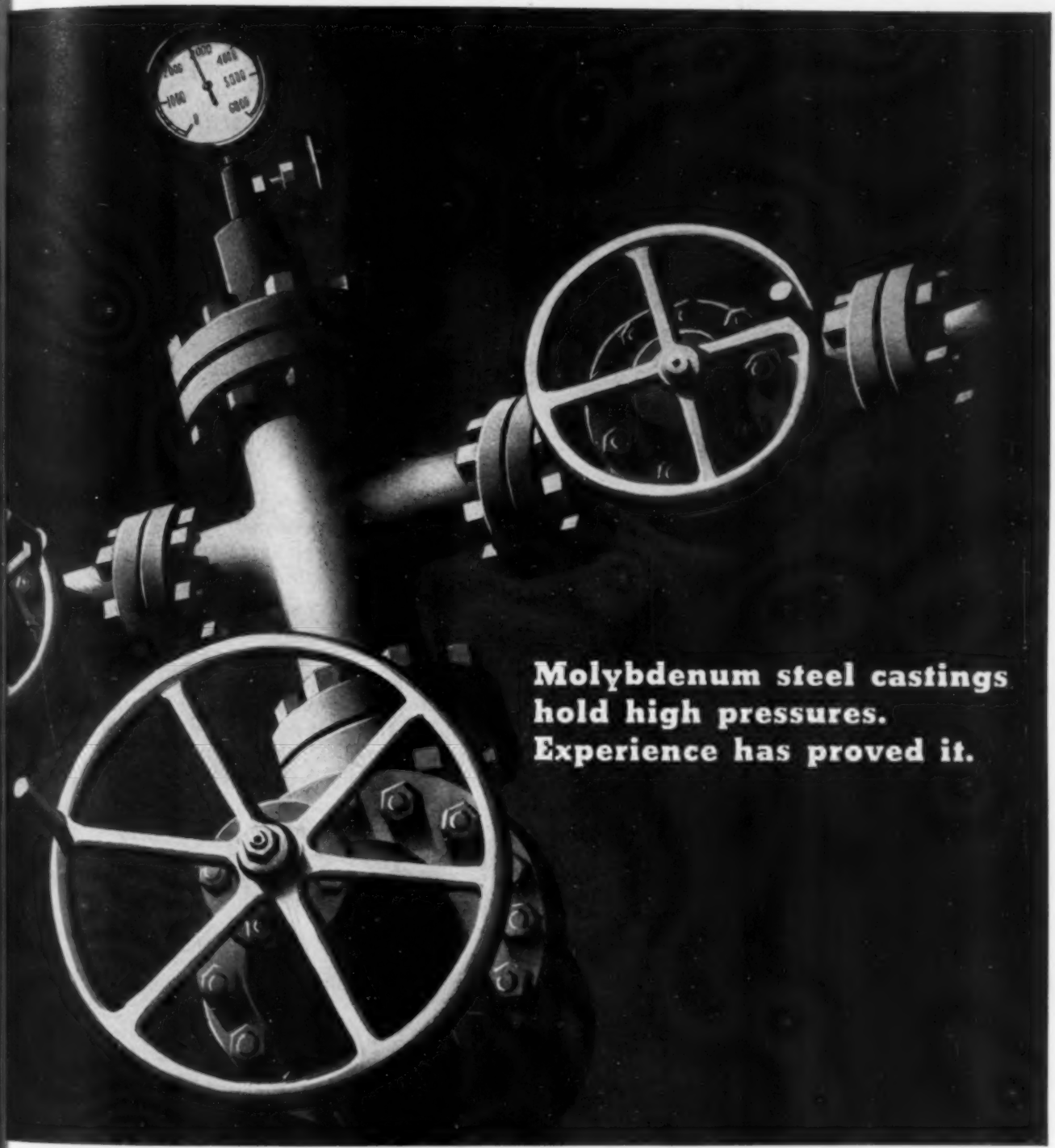
were softened in the ordinary way at 1900° F. Their structure after this treatment, while predominantly austenitic, contained also 20% or so of ferrite, Steel A containing more than Steel B. One half of each bar was reheated for 3 hr. at 1560° F. and then air cooled, with the result that a certain amount of the sigma phase was formed. Test bars were then made from each of the two steels in each of the above conditions, and the toughness tested at room temperature and at three elevated temperatures. Results are given in the attached table.

The test pieces, which were 10 mm. square, were broken on a Charpy machine, but were notched with the standard Izod notch; those tested above atmospheric temperature were heated at their respective temperatures for 30 min. before breaking.

It is probable that heating for 3 hr. at 1560° F. resulted in the formation of only a small amount of the sigma phase, and that more prolonged heating at this temperature would have caused greater embrittlement; *(Cont. on p. 752)*

Hot Toughness of Cr-Ni-W-Si Steel

BAR	TREATMENT	IMPACT VALUE AT			
		60° F.	930° F.	1290° F.	1475° F.
A	Softened	30	30	35	42
	" reheated 1560° F.	21	23	24	26
B	Softened	45	47	46	48
	" reheated 1560° F.	23	25	32	33



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tests on other bars of similar material have shown in fact that their Izod value can be reduced to 5 ft-lb. or so by prolonged heating. It is significant, however, that the bars treated for only 3 hr. had appreciably lower impact values than the normally softened bars at all the temperatures at which they were tested.

It may be concluded, therefore, that brittleness in heat resisting steels resulting from the production of the sigma phase is likely to be quite as evident while the steel is hot — at least within the range of temperature in which the phase is stable — as it undoubtedly is when the steel has cooled to atmospheric temperature. This is a matter of considerable importance in the practical use of such steels.

J. H. G. MONYPENNY
Metallurgist,
Brown, Bayley's Steel Works, Ltd.

Pit Corrosion of Magnesium Alloy Castings

AKRON, OHIO

To the Readers of METAL PROGRESS:

Recently we have encountered a corrosion phenomenon involving magnesium alloy castings, which has been costly to us and which we feel should be known to other magnesium fabricators.

Because of indoor space limitations, a number of magnesium alloy castings purchased to Army-Navy specification AN-QQ-M-56, composition A, heat treated and aged, were stored outdoors and unprotected. Composition A consists of 5.3 to 6.7% aluminum, 2.5 to 3.5% zinc, 0.15% min. manganese, and all the other elements held low. All castings had been given the usual chromium pickle at the foundry.

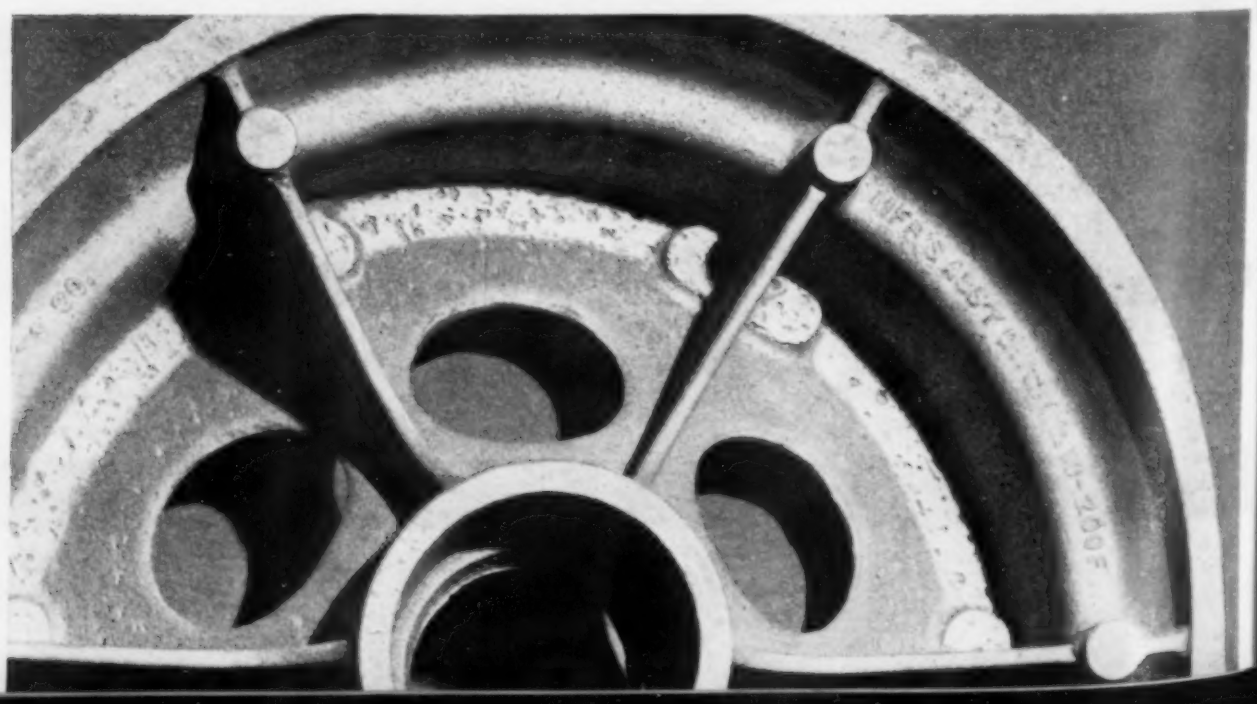
The castings were placed outside in February, 1944, and taken indoors during May, whereupon severe corrosion of the pitting type was discovered. Although pitting was present at various locations, it was concentrated at depressed areas where water had lodged and evaporated slowly. Many contained numerous pits as deep as $\frac{3}{16}$ in. and about as wide. Chemical analysis of the corrosion product lodged in the pits showed chlorine as magnesium chloride 0.71%, sulphate as magnesium sulphate 2.60%, carbonate as magnesium carbonate 96.24%. The castings were spoiled for the intended service and were scrapped.

We are now trying to determine if this corrosion pitting could develop from contact with rain water alone, or if other constituents are required which reach the water through the air.

The literature is not too clear regarding the resistance of the magnesium alloys to pit corrosion while under atmospheric exposure. Statements are made on page 108 of American Chemical Society's Monograph No. 71, "Corrosion Resistance of Metals and Alloys", by McKay and Worthington, which indicate that pitting will develop slowly, particularly in moist marine atmospheres. Other statements (American Magnesium Corp., "Magnesium Data 1943", page 3) are to the effect that magnesium alloys have excellent resistance to ordinary atmospheres over long periods of time. Our experience leads to the conclusion that the aluminum-zinc alloy must be kept completely dry and that castings should be protected by painting or other *effective* surface treatment at the earliest possible moment.

J. L. MILLER
Chief Metallurgist, Gun Mount Division
Firestone Tire & Rubber Co.

Deep Pits in Cast Magnesium Alloy Landing Wheel Center, Eaten During Four Months' Exposure to Winter Weather in Industrial Atmosphere



Industry...

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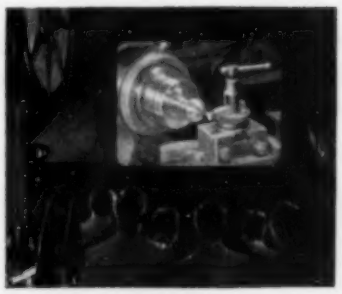

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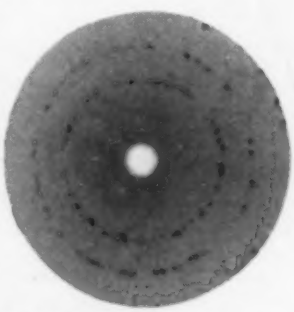
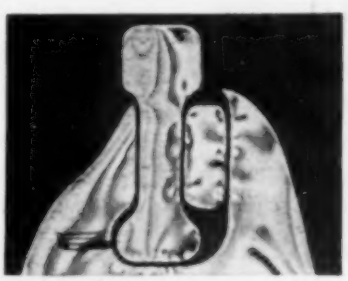


X-RAY DIFFRACTION—
Reveals the invisible

Industry is finding many practical applications for crystal analysis by x-ray diffraction. Minute particles, too small to be seen by visible light, modify and diffract x-rays. Recorded on film, the x-rays form diffraction patterns which are of great value to metallurgists and engineers in the search for better materials and methods of metal-treating.



STRESS ANALYSIS—
Previews performance

Photographic stress analysis studies, similar to the photo-elasticity illustration above, are playing an increasingly important part in product design. Study and analysis of an experimental model's behavior under simulated operating conditions enable predetermination of the product's performance.

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Personals

ARTHUR PHILLIPS, professor of metallurgy, Yale University, has been awarded the honorary degree of Doctor Honoris Causa by the University of Sao Paulo, Brazil, and has been presented a gold medal and made a director of the Associaco Brasileira de Metais, during his recent stay in that country to present a series of lectures.

Honored by Pratt & Whitney Division of Niles-Bement-Pond Co., Hartford, Conn.: A. H. d'ARCAMBAL, past president, vice-president, consulting metallurgist and general sales manager of the small tool and gage department, on the occasion of his 25th anniversary with the company.

EUGENE P. KLIER, Ph.D. in Metallurgy, University of Notre Dame, is now an instructor in metallurgy at Penn State College.

HORACE H. LESTER, physicist, and WALLACE B. KENNEDY, superintendent of production, Watertown Arsenal, have been presented the Exceptional Civilian Service Award of the War Department for extraordinary service within and beyond the call of duty.

MILDRED FERGUSON, formerly metallographer at Westinghouse Research Laboratories, is now associated with the Eclipse-Pioneer Division, Bendix Aviation Corp., Teterboro, N. J., as research metallurgist and head of the metallographic division.

JOHN R. QUINZIO, designer formerly with the Sterling Engine Co., is now with the Buffalo Foundry & Machine Co.

VICTOR F. J. TLACK, formerly president of Darwin & Milner, Inc., Cleveland, has been appointed consultant and special representative of the sales department of Latrobe Electric Steel Co. in the Cleveland office.

GILBERT R. MILLER has left the heat treat department at Bendix Aviation Corp., South Bend, Ind., to accept a position at Lennox Furnace Co., Aircraft Division, Columbus, Ohio.

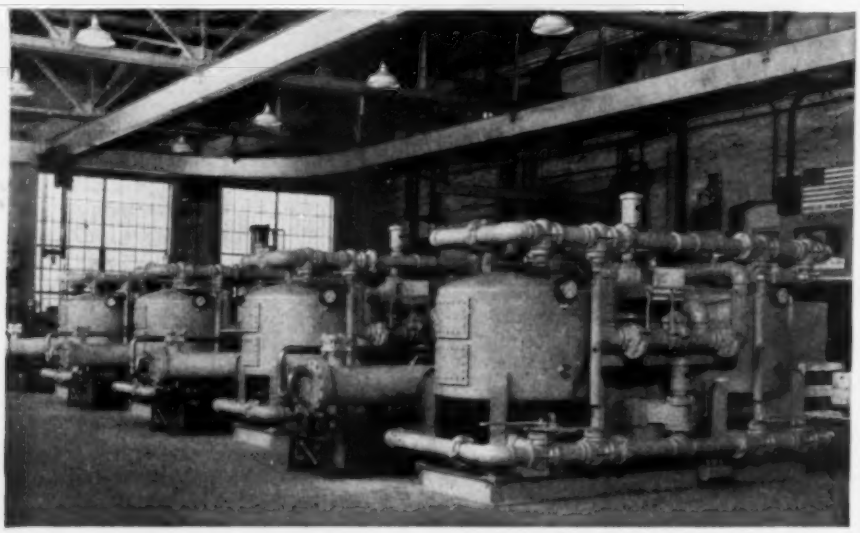
F. R. MORRAL, formerly industrial fellow, Mellon Institute for Industrial Research, is now group leader of metal trades laboratory in the technical service and development division of American Cyanamid Co., Stamford, Conn.

J. R. REYNOLDS, formerly melting foreman at Symington Gould Corp., Rochester, N. Y., is now melting foreman at General Metals Corp., Oakland, Calif.

Appointed to the National Brass and Brass Foundry Industry Advisory Committee of the O.P.A.: Fred A. MAINZER, general manager of the Pacific Brass Foundry of San Francisco.

CHARLES W. BEEM is now with Firestone Industrial Products Co., New Castle, Ind., as department manager.

ALBERT GUY is employed as metallurgist in the research laboratory of General Electric Co., Schenectady, N. Y.



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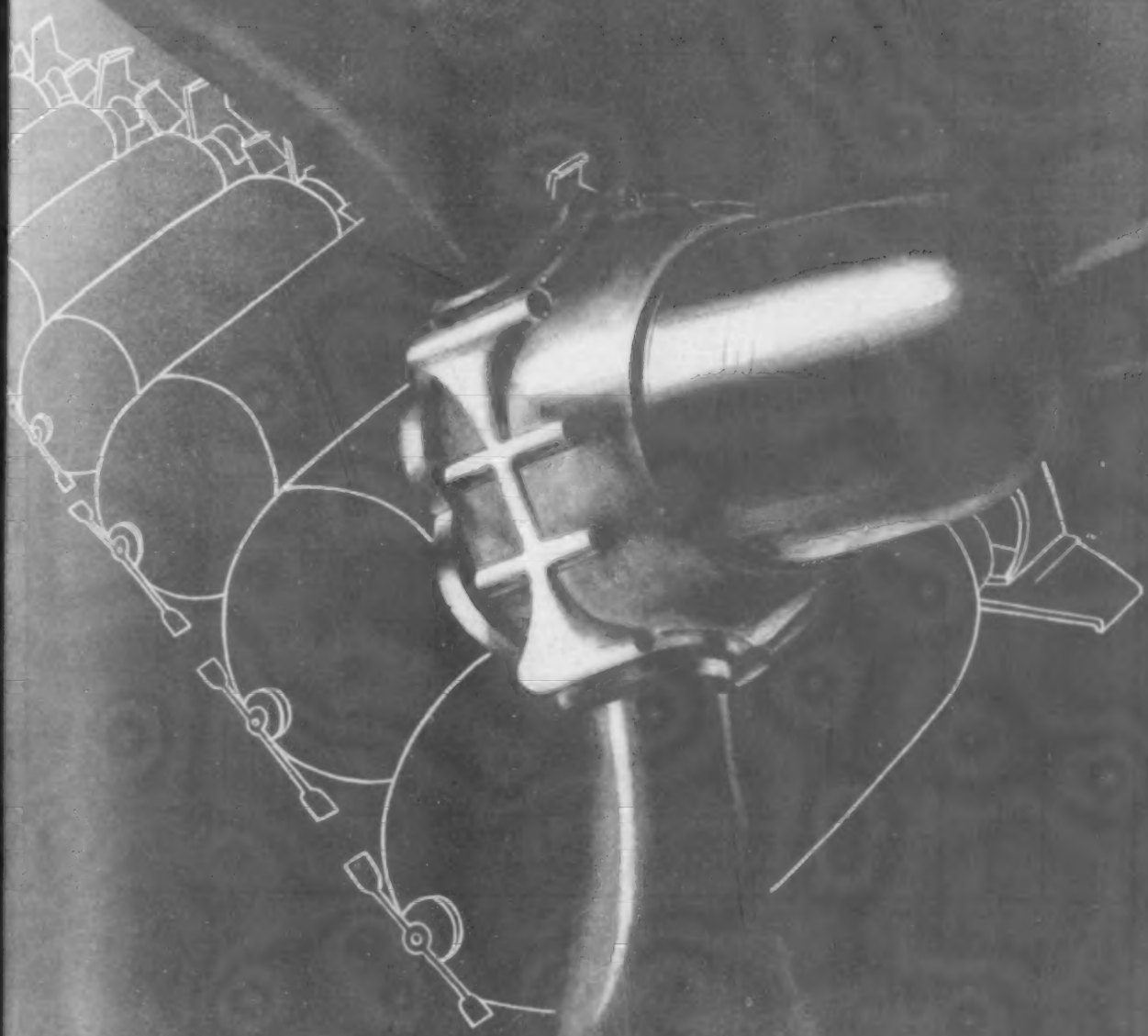


annual reference issue

october 1944

Relative Corrodibility of Some Common Metals and Alloys

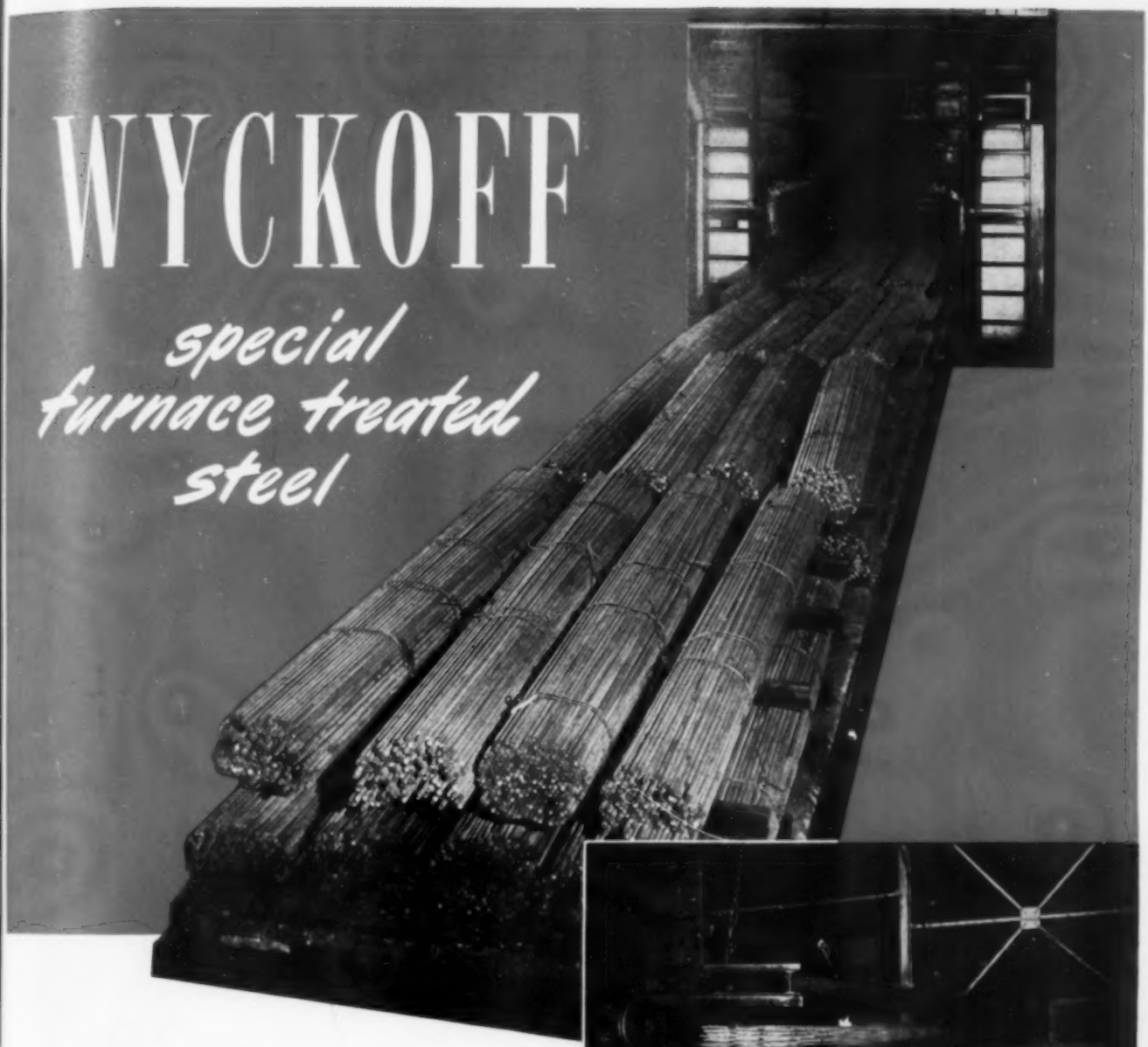
Compiled in 1933 by Jerome Strauss

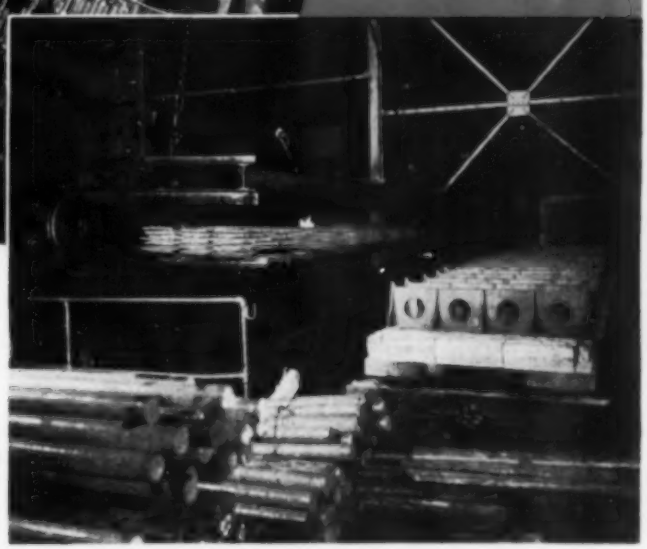
Class of Material	Nominal Composition							Atmospheres		Water					Oxidation Resistance Max. Safe Temp. °F.			Fruit, Vegetable Juices	Dairy Products	Other Food Products	Acids Moderate Concentration 5-15%					Alkalies		Salt Solutions Medium Concentration				Hot Sulphite Liquor	Dye Liquor	Refinery Crudes Below 400°F.	
	Carbon	Chromium	Nickel	Silicon	Copper			See Shore	Industrial	Domestic	Mine	Sea	Saline with H_2S	Brackish with MCl	Wet Steam	Oxidizing Gases	Reducing Fuel Gas	Sulphur Rich Gas				HCl	H_2SO_4	HNO_3	Acetic	Phosphoric	1 to 20% Sol.	Fused	NH_4Cl	$MgCl_2$	$MgSO_4$				Sweet	Sour
Ingot iron or wrought iron	0.03				0.08			P	P	P	P	PF	P	F	F				P	P	P	P	P	P	P	E		P	F	F				F	P
Low C steel	0.10				0.08			P	P	P	P	F	P	F	F				P	P	P	P	P	P	P	E		P	F	F				F	P
Low C copper steel	0.10				0.25			F	G	P	P	F	P	F	FG				P	P	P	P	P	P	P	G		P	F	F				F	P
Hot galvanized iron & steel								G	G	F	F	G	F	F					P	P	P	P	P	P	P	F		P	P	pF				P	P
Calorized iron & steel								G	G	P	P	P				1650	1650	1650				F	F	F	F								P	F	FG	FG
Gray cast iron	2.8 graphite, 0.7 combined carbon							F	G	F	F	F							P	P	P	P	P	P	P	E	F	P	P	P				F	
High silicon iron	0.60			14.25				E	E	E	G	E							G†			F	E	E	G	G	E		G	G	G				P	P
Nickel cast iron	3.30		3.50	1.50				F	G	P	P	F														E	FG							F	
Chromium cast iron	2.50	25.00		2.00				G	G	G	G	FG				1800	1800	1800															F	
Ni-Cr-Cu cast iron	3.00	2.00	14.00	1.50	6.00			G	G	G	G	G	F	F	G	1200	1200	1200	F			F	F	P	G	G	G	G	F	F	F		F	F	G	G
Nickel steel: Low Ni	0.18		3.00					F	F	F	P	F							P	P		P	P	P	P	E	G	P	F	F					
High Ni	0.30		28.00					G	G	G	FG	E							F			F	G	P	P	E	G	F	E	E					
Chromium steels: 5% Cr	0.15	5.00						F	F	F	P	P	P	P	F	1200	1200	1200	P			P	P	P	P	G		P	P	F				G	G
12% Cr	.10 max.	12.00						G	G	G	F	F		F	G	1400	1400	1400	G		G	P	P	G	G	E		G	G	G				E	
17% Cr	.10 max.	17.00						G	G	G	G	G		G	G	1600	1600	1500	G	G	G	P	P	G	E‡	E		G	G	G				E	E
17% Cr, 4% Mo	.10 max.	17.00				Mo 4.0		G	G																										
27% Cr	.50 max.	27.00						G	G	E	G	G		G	E	1900	1900	1800	E	G	E	P	P	E	F	G		E	E	E					
Silcrome, (8% Cr, 3% Si)	0.45	8.25		3.50				G	G	F	F	F	F	F	F		1500		F			P	P	E	G	G						GE	PG		
Stellite	3.0 max.	30.00				Co 55.0	W 15.0	E	E	E	E	E	E	G	E	2000	2000		E	E	E	F	G	E	G	E		E	E	E				G	G	E	E
Cr-Ni steels: 8-20	0.20	8.00	20.00					G	G	G	G	G				1600	1600					P	G	F	G	G	G	G						G	E	
18-8, 4% Mo	0.15	18.00	8.00			Mo 4.0		E	G	E	G	G	E	E	E							P	P	G	F	G	G	G	G	E	E			GE	E	E
18-8	0.10	18.00	8.00					E	G	E	G	G	E	G	E	1550	1550	{300 to 1300	G	E	E	P	P	F	G	G	G	E	G	FG	E	E		GE	F	E	E
18-12	0.10	18.00	12.00					E	G	E	G	G										P	P	F	G	G	G	F						G	E	E
18-35	.50 max.	18.00	35.00	1.00				E	G	E	FG	G				1900	1900	1900	G			P	P	G	P	G	G	F						G	P		
25-12	.25 max.	25.00	12.00					E	G	E	G	G	E	G	E	2100			G	E	E	P	P	G	P	G	G	G						GE	G	E	
26-24	.15 max.	26.00	24.00	3.00				E	G	E	G	G	E	G	E	2100	2000		G	E	E	P	P	F	G	G	G	G	E	E	E			E	G	E	
Commercially pure Ni			99.20					E	G	E	G	E	G			1300	2000	P	G	GE	GE	G	G	P	G	G	G	G	E	E	G			P	P	G	
Nickel alloys: Monel metal	0.15		67.50	0.50	28.50	Mn 1.50		E	G	E	PE	E	G		E	900	2000	P	G	FE	FG	FG	G	P	G	G	G	E	E	G	E			P	G	E	F
Nichrome, 60-15	0.12	15.00	60.00					G	G	E	G	G				1475 to 2100		P	G			F	F	F	G	G	G	E	G					P	P		
Inconel, 14% Cr		14.00	80.00			Fe 6.0		G	G		G	G				2000	2000		E	E	E																
80% Ni, 20% Cr		20.00	80.00					G	G	E	G	G							G			F	G	P	G	G	G	E								
Hastelloy		14.00	58.00			Mo 17	W 5.0	E	E	E	G	E	E	E	E				E	G	G	G	FG	G	G	E	E	G	G	G	G				E	G	G	G
Commercially pure Cu					99.90			G	G	G	FG	G							FG	P	F	F	FG	P	FG	FG	FG							G	FG		
Copper alloys: Red brass					85.00	Zn 15.0		G	G	FG	FG	G							FG	P	P	F	FG	P	FG	FG	FG							G	FG		
Tobin bronze					60.00	Zn 39.2	Sn .75	G	FG		F	G	F							P	P	P	F	P	P	F	F							G	F	FG	
Phosphor bronze					95.00	Sn 5.0	Zn 1.5	G	FG		F	G							P	P	F	P	FG	P	P	FG	FG							G	FG		
Silicon bronze				3.00	95.00	Mn 1.0 or	{Sn .5	G	G		FG	G							G	P	P	F	G	P	P	G	G							G	FG	G	
Aluminum bronze					90.00	Al 9.0	{Fe .5	G	G		FG	G							FG	P	P	P	FG	P	P	FG	FG							G	FG		
Nickel silver			20.00		75.00	Zn 5.0	Ni .5	G	G		G	G							G	P	P	F	G	P	P	G	G							G	FG		
Admiralty metal					70.00	Zn 29.0	Sn 1.0	G	G		FG	G							FG		P	P	FG	P	P	FG	FG	P								FG		
Commercially pure Al						Al 99.20		F	F	PG	P	F							G	G	G	P	P	P	P	F	P							P	F		
Commercially pure Sn										E										G	P	P	P	P	P	P	G	P									
Commercially pure Pb					0.06	Pb 99.90		G	G	PG	G	G							P	P	P	F	G	P	P	G	P	P							P	F		

F = Excellent; almost unlimited service E = Fair; only to be used in temporary construction FG = F to G PE = P to E PG = P to G ‡ Below 500°C

WYCKOFF

special furnace treated steel





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TO MANY OF YOUR POST-WAR COLD FINISHED CARBON AND ALLOY REQUIREMENTS

WYCKOFF STEEL CO.

General Offices: **PITTSBURGH 30, PENNA.**

Works: **AMBRIDGE, PENNA.; CHICAGO, ILL. NEWARK, N. J.; PUTNAM, CONN.**

Manufacturers of Carbon and Alloy Steels . . . Turned and Polished Shafting . . . Turned and Ground Shafting . . . Wide Flats up to 12" x 2".

COMPLETE ANNEALING AND HEAT TREATING FACILITIES

Color Codes for Marking Metals and Alloys

Steels from Bureau of Standards' Simplified Practice Recommendation R166-37 — *Non-Ferrous Metals from Federal Standard Stock Catalogue*

S.A.E. Number	Code Color
	Carbon Steels
1010	White
1015	do
X1015	do
1020	Brown
X1020	do
1025	Red
X1025	do
1030	Blue
1035	do
1040	Green
X1040	do
1045	Orange
X1045	do
1050	Bronze
1095	Aluminum
	Free Cutting Steels
1112	Yellow
X1112	do
1120	Yellow and brown
X1314	Yellow and blue
X1315	Yellow and red
X1335	Yellow and black
X1340	do
	Manganese Steels
T1330	Orange and green
T1335	do
T1340	do
T1345	Orange and red
T1350	do
	Nickel-Chromium Steels
3115	Blue and black
3120	do
3125	Pink
3130	Blue and green
3135	do
3140	Blue and white
X3140	do
3145	do
3150	Blue and brown
3215	Blue and purple
3220	do
3230	do
3240	Blue and aluminum
3245	do
3250	Blue and bronze
3312	Orange and black
3325	do
3335	Blue and orange
3340	do
3415	Blue and pink
3435	Orange and aluminum
3450	Black and bronze

S.A.E. Number	Code Color
	Nickel Steels
2015	Red and brown
2115	Red and bronze
2315	Red and blue
2320	do
2330	Red and white
2335	do
2340	Red and green
2345	do
2350	Red and aluminum
2515	Red and black
	Molybdenum Steels
4130	Green and white
X4130	Green and bronze
4135	Green and yellow
4140	Green and brown
4150	do
4340	Green and aluminum
4345	do
4615	Green and black
4620	do
4640	Green and pink
4815	Green and purple
4820	do
	Chromium Steels
5120	Black
5140	Black and white
5150	do
52100	Black and brown
	Chromium-Vanadium Steels
6115	White and brown
6120	do
6125	White and aluminum
6130	White and yellow
6135	do
6140	White and bronze
6145	White and orange
6150	do
6195	White and purple
	Tungsten Steels
71360	Brown and orange
71660	Brown and bronze
7260	Brown and aluminum
	Silicon-Manganese Steels
9255	Bronze and aluminum
9260	do

Metal	Grade	Specifications: Federal	Specifications: Navy	Specifications: A.S.T.M.	Markings: Background	Markings: Stripe
Alclad					Lead & tan	Black
Aluminum	B	QQ-A-451	46-A-2		do	Brown
soft	A		46-A-3		do	White
half hard	B		46-A-3		do	Green
three-quarters	C		46-A-3		do	Yellow
hard	D		46-A-3		do	Red
Aluminum alloy, soft			46-A-4		Lead & red	None
half hard	B		47-A-4		do	Blue
hard	D		47-A-4		do	Brown
heat treated			47-A-3		do	Black
heat treated & rolled			47-A-3		do	White
Navy alloy A-2					Lead & white	None
do, heat treated					do	Black
Navy alloy No. 2, annealed					do	Brown
do, heat treated					do	Green
Navy alloy No. 4, soft					Lead & yellow	Blue
Brass			46-B-26		Brown & green	Black
Commercial, type 1	A	QQ-B-611		B15-18	do	Blue
do	B	QQ-B-611		B16-18	do	Lead
do	C	QQ-B-611			do	Tan
Commercial, type 2	B	QQ-B-611	47-B-2		do	Red
do	C	QQ-B-611			do	White
Naval, rolled			46-B-6		do	Yellow
Bronze	1	QQ-B-701	46-B-25		Brown & tan	Black
	2	QQ-B-701	46-B-25		do	Blue
	3	QQ-B-701	46-B-25		do	Green
	4	QQ-B-701	46-B-25		do	Lead
	5	QQ-B-701	46-B-25		do	Red
	6	QQ-B-701	46-B-25		do	White
Aluminum			46-B-19		Brown & white	Black
Journal			46-B-9		do	Blue
Manganese		QQ-B-721	46-B-16	B7-27	do	Green
Muntz Metal					do	Lead
Phosphor			46-B-14		do	Tan
Rivet					do	Red
Special					do	Yellow
Copper, hard drawn		QQ-C-501	47-C-2		Red & white	Black
Soft drawn		QQ-C-501	47-C-2		do	Blue
Phosphor	A	QQ-C-571	46-C-3		Red & yellow	Black
Silicon		QQ-C-581	46-C-2	B53-27	do	Brown
Nickel		QQ-C-541	46-M-7		do	Green
Nickel	A	QQ-N-301	46-N-2	B39-22	Green & lead	Black
	B	QQ-N-301	46-N-2	B39-22	do	Blue
Manganese-Nickel			46-N-3		Green & tan	Black
Nickel-Silver	A	QQ-N-321	46-S-3		do	Lead
Tin, phosphor		QQ-T-351	46-T-2	B51-27	Green & yellow	Black
Zinc	A	QQ-Z-351	46-Z-1		Green & white	Black
	B	QQ-Z-351	46-Z-1		do	Blue
	C	QQ-Z-351	46-Z-1		do	Brown
	D	QQ-Z-351	46-Z-1		do	Lead
	E	QQ-Z-351	46-Z-1		do	Tan

Plus these

NEW DESIGN POSSIBILITIES

with Carpenter Stainless!

That gleam in your designer's eye probably means one thing: you're planning to launch some exciting new or redesigned product in the postwar market.

Very likely Stainless Steel will feature in your plans—for Stainless not only provides resistance to corrosion, heat and wear, but high strength/weight ratio, special physicals, and gleaming surface finishes that stay everlastingly bright.

As the pioneer in the development of Stainless Steels, and inventor of Free-Machining Stainless Steels, we'd like to apply our diversified peacetime and wartime experience to help solve your specific Stainless problems.

There are three ways you can benefit by working with Carpenter in your postwar planning:

1. By starting with Carpenter Stainless Steels, which through rigid controls in manufacture, can be counted on to have the same uniform fabricating qualities, lot after lot.

2. Through a service program which aims to help Stainless users select the analysis that will best meet the particular fabrication, corrosion, and physical requirements.

3. By taking advantage of Carpenter metallurgical and engineering assistance in solving new and different problems of fabrication. This helps prevent trouble *before it starts*, speeds production, and reduces fabricating costs.

Give Your Product These Advantages

- Sales Appeal
- Everlasting Beauty
- Freedom from Rust
- No Plating to Peel
- Weight Saving
- Strength and Rigidity
- Ease of Assembly
- Fewer Service Complaints

Take the first step to secure this helpful Stainless design-engineering cooperation by calling in your nearby Carpenter representative. Talk over your problems with him—get the benefit of his long Stainless experience. If you have not already received a copy of our 98-page book, "Working Data for Carpenter Stainless Steels," drop us a line on your company letterhead indicating your title.

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National Emergency Alloy Steels*

Openhearth Alloy and Electric Furnace Alloy Steels; Blooms, Billets, Slabs, Bars and Hot Rolled Strip.

Revised May 26, 1944

Adopted	Abandoned	Designation	C	Mn	Si (a)	Ni	Cr	Mo	Hardenability (b) Low	Hardenability (b) High
Carbon-Manganese Steels										
8/17/42		NE1330	0.28-0.33	1.60-1.90	0.20-0.35	(c)	(d)	(e)	1.53	4.24
8/17/42		NE1335	0.33-0.38	1.60-1.90	0.20-0.35	(c)	(d)	(e)	1.67	4.54
8/17/42		NE1340	0.38-0.43	1.60-1.90	0.20-0.35	(c)	(d)	(e)	1.80	4.79
8/17/42		NE1345	0.43-0.48	1.60-1.90	0.20-0.35	(c)	(d)	(e)	1.91	5.10
8/17/42		NE1350	0.48-0.53	1.60-1.90	0.20-0.35	(c)	(d)	(e)	2.02	5.39
Carbon-Chromium Steels (f)										
8/17/42		NE52100 C	0.95-1.10	0.25-0.45	0.20-0.35	0.35max.	0.40-0.60	0.08max.	1.19	4.0
8/17/42		NE52100 B	0.95-1.10	0.25-0.45	0.20-0.35	0.35max.	0.90-1.15	0.08max.	1.74	6.0 (g)
8/17/42		NE52100 A	0.95-1.10	0.25-0.45	0.20-0.35	0.35max.	1.30-1.60	0.08max.	2.40	8.7 (g)
Manganese-Molybdenum Steels										
8/17/42	8/15/43	NE8020	0.18-0.23	1.00-1.30	0.20-0.35			0.10-0.20		
8/17/42	12/17/42	NE8022	0.20-0.25	1.00-1.30	0.20-0.35			0.10-0.20		
1/21/42	8/17/42	NE8024	0.22-0.28	1.00-1.30	0.20-0.35			0.10-0.20		
1/21/42	8/17/42	NE8124	0.22-0.28	1.30-1.60	0.20-0.35			0.25-0.35		
1/21/42	8/17/42	NE8233	0.30-0.36	1.30-1.60	0.20-0.35			0.10-0.20		
1/21/42	8/17/42	NE8245	0.42-0.49	1.30-1.60	0.20-0.35			0.10-0.20		
1/21/42	12/17/42	NE8239	0.35-0.42	1.30-1.60	0.20-0.35			0.20-0.30		
1/21/42	8/15/43	NE8442	0.40-0.45	1.30-1.60	0.20-0.35			0.30-0.40		
1/21/42	8/17/42	NE8447	0.43-0.50	1.30-1.60	0.20-0.35			0.30-0.40		
1/21/42	8/17/42	NE8547	0.43-0.50	1.30-1.60	0.20-0.35			0.40-0.60		
Nickel-Chromium-Molybdenum Steels										
5/26/44		NE8612	0.10-0.15	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	1.07	3.68
8/17/42	5/26/44	NE8613	0.12-0.17	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25		
8/17/42		NE8615	0.13-0.18	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	1.34	4.02
8/17/42		NE8617	0.15-0.20	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	1.43	4.25
1/21/42		NE8620	0.18-0.23	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	1.52	4.47
5/26/44		NE8622	0.20-0.25	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	1.65	4.77
5/26/44		NE8625	0.23-0.28	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	1.72	4.96
5/26/44		NE8627	0.25-0.30	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	1.84	5.23
1/21/42		NE8630	0.28-0.33	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	1.91	5.47
5/26/44		NE8632	0.30-0.35	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	2.00	5.64
12/17/42		NE8635	0.33-0.38	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	2.22	6.35
12/17/42		NE8637	0.35-0.40	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	2.28	6.50
12/17/42		NE8640	0.38-0.43	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	2.38	6.75
12/17/42		NE8642	0.40-0.45	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	2.44	6.90
12/17/42		NE8645	0.43-0.48	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	2.53	7.15
5/26/44		NE8647	0.45-0.50	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	2.59	7.35
12/17/42		NE8650	0.48-0.53	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25	2.67	7.55
5/26/44		NE8712	0.10-0.15	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	1.30	4.01
5/26/44		NE8715	0.13-0.18	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	1.48	4.39
5/26/44		NE8717	0.15-0.20	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	1.58	4.63
5/26/44		NE8720	0.18-0.23	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	1.72	4.98
5/26/44		NE8722	0.20-0.25	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	1.83	5.20
1/21/42	8/17/42	NE8724	0.22-0.28	0.70-0.95	0.20-0.35	0.40-0.60	0.40-0.60	0.20-0.30		
5/23/44		NE8725	0.23-0.28	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	1.95	5.50
5/26/44		NE8727	0.25-0.30	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	2.03	5.70
5/26/44		NE8730	0.28-0.33	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	2.14	5.95
5/26/44		NE8732	0.30-0.35	0.70-0.90	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	2.22	6.15
5/26/44		NE8735	0.33-0.38	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	2.44	6.90
5/26/44		NE8737	0.35-0.40	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	2.52	7.05
1/21/42	12/17/42	NE8739	0.35-0.42	0.75-1.00	0.20-0.35	0.40-0.60	0.40-0.60	0.20-0.30		
5/26/44		NE8740	0.38-0.43	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	2.62	7.35
5/26/44		NE8742	0.40-0.45	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	2.70	7.50
1/21/42	12/17/42	NE8744	0.40-0.47	0.75-1.00	0.20-0.35	0.40-0.60	0.40-0.60	0.20-0.30		
5/26/44		NE8745	0.43-0.48	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	2.79	7.75
5/26/44		NE8747	0.45-0.50	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	2.86	7.95
1/21/42	12/17/42	NE8749	0.45-0.52	0.75-1.00	0.20-0.35	0.40-0.60	0.40-0.60	0.20-0.30		
5/26/44		NE8750	0.48-0.53	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.20-0.30	2.95	8.20
1/21/42	8/17/42	NE8817	0.15-0.20	0.70-0.95	0.20-0.35	0.40-0.60	0.40-0.60	0.30-0.40		
1/21/42	12/17/42	NE8949	0.45-0.52	1.00-1.30	0.20-0.35	0.40-0.60	0.40-0.60	0.30-0.40		

Adopted	Abandoned	Designation	C	Mn	Si (a)	Ni	Cr	Mo	Hardenability (b) Low	Hardenability (b) High
Silicon-Manganese and Silicon-Manganese-Chromium Steels										
8/17/42		NE9255	0.50-0.60	0.70-0.95	1.80-2.20	(c)	(d)	(e)	2.20	6.60
8/17/42		NE9260	0.55-0.65	0.70-1.00	1.80-2.20	(c)	(d)	(e)	2.34	7.15
8/15/43		NE9261	0.55-0.65	0.70-1.00	1.80-2.20	(c)	0.10-0.25	(e)	2.60	9.20
8/17/42		NE9262	0.55-0.65	0.70-1.00	1.80-2.20	(c)	0.25-0.40	(e)	3.36	10.5
Manganese-Nickel-Chromium-Molybdenum Steels (h)										
8/17/42		NE9415	0.13-0.18	0.80-1.10	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	1.15	3.52
5/26/44		NE9417	0.15-0.20	0.80-1.10	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	1.23	3.70
8/17/42		NE9420	0.18-0.23	0.80-1.10	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	1.34	3.99
8/17/42		NE9422	0.20-0.25	0.80-1.10	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	1.42	4.17
8/15/43		NE9425	0.23-0.28	0.90-1.20	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	1.66	4.72
5/26/44		NE9427	0.25-0.30	0.90-1.20	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	1.72	4.89
8/17/42		NE9430	0.28-0.33	0.90-1.20	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	1.81	5.10
5/26/44		NE9432	0.30-0.35	0.90-1.20	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	1.88	5.25
8/17/42		NE9435	0.33-0.38	0.90-1.20	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	1.98	5.45
8/17/42		NE9437	0.35-0.40	0.90-1.20	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	2.03	5.60
8/17/42		NE9440	0.38-0.43	0.90-1.20	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	2.12	5.80
8/17/42		NE9442	0.40-0.45	1.00-1.30	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	2.36	6.50
8/17/42		NE9445	0.43-0.48	1.00-1.30	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	2.45	6.75
5/26/44		NE9447	0.45-0.50	1.20-1.50	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	2.90	8.05
8/17/42		NE9450	0.48-0.53	1.20-1.50	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15	2.99	8.30
Manganese-Silicon-Nickel-Chromium-Molybdenum Steels										
8/17/42	5/26/44	NE9537 (i)	0.35-0.40	1.20-1.50	0.40-0.60	0.40-0.70	0.40-0.60	0.15-0.25		
8/17/42	5/26/44	NE9540 (i)	0.38-0.43	1.20-1.50	0.40-0.60	0.40-0.70	0.40-0.60	0.15-0.25		
8/17/42	5/26/44	NE9542 (i)	0.40-0.45	1.20-1.50	0.40-0.60	0.40-0.70	0.40-0.60	0.15-0.25		
8/15/43	5/26/44	NE9545 (i)	0.43-0.48	1.20-1.50	0.40-0.60	0.40-0.70	0.40-0.60	0.15-0.25		
8/17/42	5/26/44	NE9550 (i)	0.48-0.53	1.20-1.50	0.40-0.60	0.40-0.70	0.40-0.60	0.15-0.25		
Manganese-Silicon-Chromium Steels										
8/17/42	8/15/43	NE9630	0.28-0.33	1.20-1.50	0.40-0.60		0.40-0.60			
8/17/42	8/15/43	NE9635	0.33-0.38	1.20-1.50	0.40-0.60		0.40-0.60			
8/17/42	8/15/43	NE9637	0.35-0.40	1.20-1.50	0.40-0.60		0.40-0.60			
8/17/42	8/15/43	NE9640	0.38-0.43	1.20-1.50	0.40-0.60		0.40-0.60			
8/17/42	8/15/43	NE9642	0.40-0.45	1.30-1.60	0.40-0.60		0.40-0.60			
8/17/42	8/15/43	NE9645	0.43-0.48	1.30-1.60	0.40-0.60		0.40-0.60			
8/17/42	8/15/43	NE9650	0.48-0.53	1.30-1.60	0.40-0.60		0.40-0.60			
Nickel-Molybdenum Steels (j)										
5/26/44		NE9722	0.20-0.25	0.50-0.80	0.20-0.35	0.40-0.70	0.10-0.25	0.15-0.25	0.90	3.31
5/26/44		NE9727	0.25-0.30	0.50-0.80	0.20-0.35	0.40-0.70	0.10-0.25	0.15-0.25	1.00	3.63
5/26/44		NE9732	0.30-0.35	0.50-0.80	0.20-0.35	0.40-0.70	0.10-0.25	0.15-0.25	1.09	3.92
5/26/44		NE9737	0.35-0.40	0.50-0.80	0.20-0.35	0.40-0.70	0.10-0.25	0.15-0.25	1.18	4.16
5/26/44		NE9742	0.40-0.45	0.50-0.80	0.20-0.35	0.40-0.70	0.10-0.25	0.15-0.25	1.27	4.42
5/26/44		NE9745	0.43-0.48	0.50-0.80	0.20-0.35	0.40-0.70	0.10-0.25	0.15-0.25	1.31	4.57
5/26/44		NE9747	0.45-0.50	0.50-0.80	0.20-0.35	0.40-0.70	0.10-0.25	0.15-0.25	1.34	4.68
5/26/44		NE9750	0.48-0.53	0.50-0.80	0.20-0.35	0.40-0.70	0.10-0.25	0.15-0.25	1.39	4.84
5/26/44		NE9763	0.60-0.67	0.50-0.80	0.20-0.35	0.40-0.70	0.10-0.25	0.15-0.25	1.55	5.05
5/26/44		NE9768	0.64-0.72	0.50-0.80	0.20-0.35	0.40-0.70	0.10-0.25	0.15-0.25	1.60	4.65
Nickel-Chromium-Molybdenum Steels (k)										
5/26/44		NE9830 (i)	0.28-0.33	0.70-0.90	0.20-0.35	0.85-1.15	0.70-0.90	0.20-0.30	2.91	8.45
5/26/44		NE9832 (i)	0.30-0.35	0.70-0.90	0.20-0.35	0.85-1.15	0.70-0.90	0.20-0.30	3.02	8.75
5/26/44		NE9835 (i)	0.33-0.38	0.70-0.90	0.20-0.35	0.85-1.15	0.70-0.90	0.20-0.30	3.18	9.05
5/26/44		NE9837 (i)	0.35-0.40	0.70-0.90	0.20-0.35	0.85-1.15	0.70-0.90	0.20-0.30	3.26	9.30
5/26/44		NE9840 (i)	0.38-0.43	0.70-0.90	0.20-0.35	0.85-1.15	0.70-0.90	0.20-0.30	3.41	9.65
5/26/44		NE9842 (i)	0.40-0.45	0.70-0.90	0.20-0.35	0.85-1.15	0.70-0.90	0.20-0.30	3.50	9.85
5/26/44		NE9845 (i)	0.43-0.48	0.70-0.90	0.20-0.35	0.85-1.15	0.70-0.90	0.20-0.30	3.62	10.2
5/26/44		NE9847 (i)	0.45-0.50	0.70-0.90	0.20-0.35	0.85-1.15	0.70-0.90	0.20-0.30	3.70	10.5
5/26/44		NE9850 (i)	0.48-0.53	0.70-0.90	0.20-0.35	0.85-1.15	0.70-0.90	0.20-0.30	3.83	10.8
Triple Steels for Carburizing (l)										
5/26/44		NE9912	0.10-0.15	0.50-0.70	0.20-0.35	1.00-1.30	0.40-0.60	0.20-0.30	1.23	3.92
5/26/44		NE9915	0.13-0.18	0.50-0.70	0.20-0.35	1.00-1.30	0.40-0.60	0.20-0.30	1.41	4.29
5/26/44		NE9917	0.15-0.20	0.50-0.70	0.20-0.35	1.00-1.30	0.40-0.60	0.20-0.30	1.50	4.52
5/26/44		NE9920	0.18-0.23	0.50-0.70	0.20-0.35	1.00-1.30	0.40-0.60	0.20-0.30	1.64	4.86
5/26/44		NE9922	0.20-0.25	0.50-0.70	0.20-0.35	1.00-1.30	0.40-0.60	0.20-0.30	1.74	5.10
5/26/44		NE9925	0.23-0.28	0.50-0.70	0.20-0.35	1.00-1.30	0.40-0.60	0.20-0.30	1.86	5.40

Notes

*All National Emergency Steels are subject to the conditions concerning chemical ranges and phosphorus and sulphur maxima as outlined for standard alloy steels on pages 14 to 17 inclusive in the latest revision of American Iron & Steel Institute's Steel Product Manual No. 10, entitled "Alloy Steels", and to the standard permissible variations from specified ranges as listed on page 26 of that Manual. Large sections are subject to modifications of carbon content only to a range of 0.10 (10 points); see page 25 of Manual No. 10.

Phosphorus and Sulphur Limits: When basic electric furnace steel is specified, phosphorus and sulphur limits are to be 0.025% max. each; for basic openhearth steel 0.040% max. each; for acid openhearth or electric steel 0.050% max. each. (These elements not used in computing hardenability.)

(a) For basic steel. Lowest minimum silicon limit to be specified for acid steel is 0.15%.

(b) Not part of the specifications. Computed by Grossmann's methods as outlined in "Metal Progress" Data Sheet No. 29, as modified by Crafts and Lamont, for grain sizes 8 and 5 (low and high side respectively).

(c) Supposedly none. Hardenability computations assume 0.10-0.25.

(d) Ditto. Assumed 0.05-0.10.

(e) Ditto. Assumed 0.00-0.08.

(f) NE52100 steels are for ball and roller bearings. Copper is limited to 0.25% max. in all analyses, and limits for inclusions are to be according to A.S.T.M. specification E45-5a.

(g) Doubtful, from unknown effect of undissolved carbides.

(h) NE9400 series, as established Aug. 17, 1942, had high-silicon (0.40-0.60%), and low nickel and chromium (0.20 to 0.40% each). Silicon, nickel and chromium were dropped to their present ranges on Aug. 15, 1943.

(i) For large sections only.

(j) NE9700 series has hardenability characteristics similar to A4000 series.

(k) NE9800 series includes deep hardening steels with hardenability between NE8700 and A4300 series.

(l) NE9900 series includes higher nickel carburizing steels with similar hardenability to NE8700.

T&W FORGINGS

usually cost less at the point of assembly

In forgings you can get metal quality in the exact degree required to meet a specific service condition. Such metal qualities as may be required, can be developed by forging and heat treating processes that are controllable at every stage of production. Heat treating forgings is a straight-forward production procedure that usually results in uniformity of physical properties in quantities of duplicate parts. T & W forging craftsmen, utilizing the most modern types of forging and heat treating equipment with a deft skill, achieve uniformity in a degree that results in reducing the time and expense of inspecting and checking forgings to a minimum. Matching forging skills with the proper equipment is the basic reason why T & W forgings *usually cost less at the point of assembly*. Ask a T & W Forging Engineer how T & W Forgings can help you win the coming battle of costs.

This forging is one-half of an assembly which is formed by welding two identical forgings together around the outer circumference. In this forging, proper grain flow is highly important to give it qualities to resist fatigue stresses.

TRANSUE & WILLIAMS

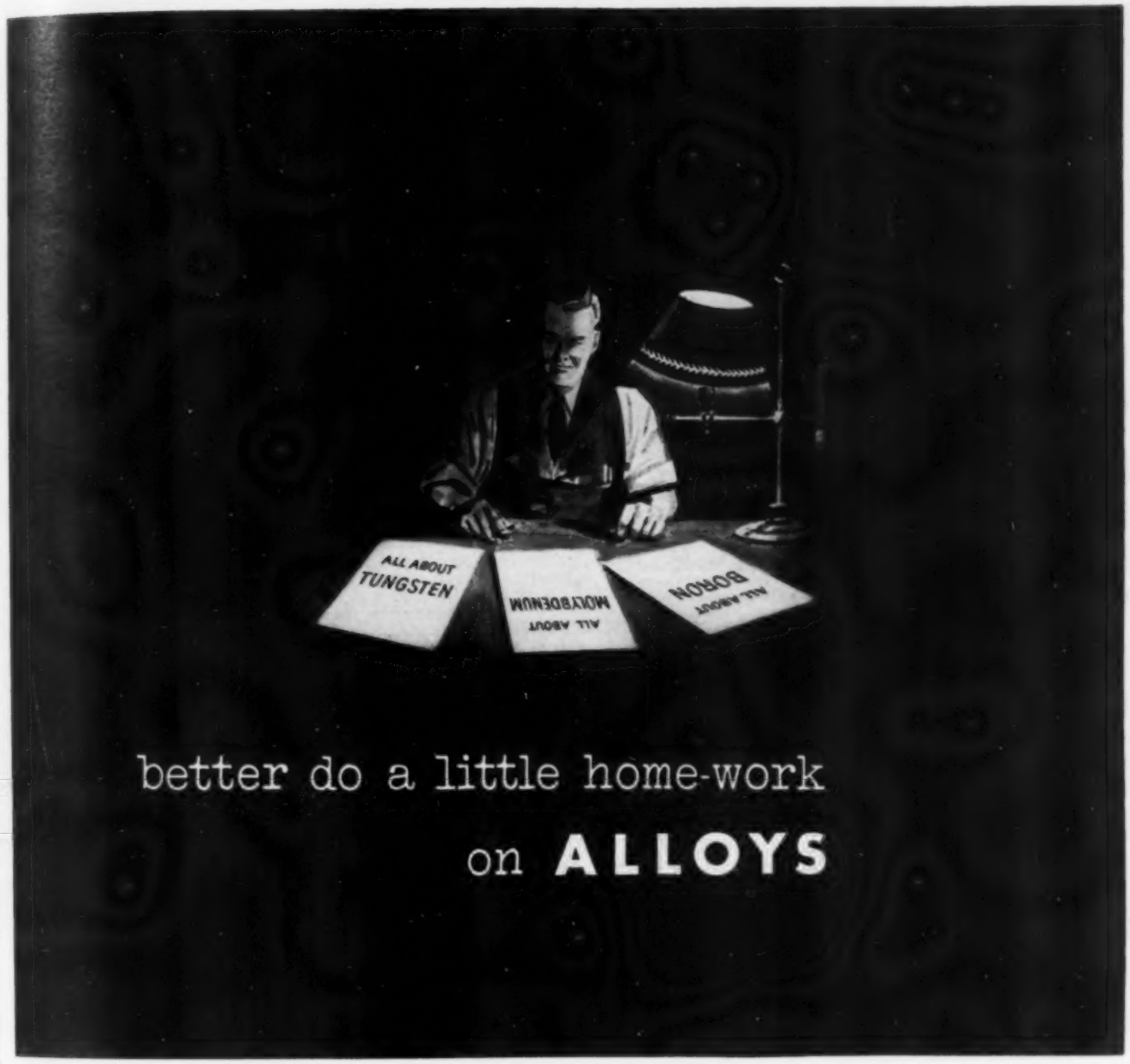
STEEL FORGING CORPORATION • ALLIANCE, O.

SALES OFFICES: NEW YORK, PHILADELPHIA, CHICAGO, INDIANAPOLIS, DETROIT AND CLEVELAND

Temperature Conversions

Albert Sauveur type of table. Look up reading in middle column; if in degrees Centigrade, read Fahrenheit equivalent in right hand column; if in degrees Fahrenheit, read Centigrade equivalent in left hand column. Values as printed in "Bethlehem Alloy Steels".

−459.4 to 0			0 to 100						100 to 1000						1000 to 2000						2000 to 3000					
C		F	C		F	C		F	C		F	C		F	C		F	C		F	C		F	C		F
−273	*−459.4*		−17.8	*0*	32	10.0	*50*	122.0	38	*100*	212	260	*500*	932	538	*1000*	1832	816	*1500*	2732	1093	*2000*	3632	1371	*2500*	4532
−268	*−450*		−17.2	*1*	33.8	10.6	*51*	123.8	43	*110*	230	266	*510*	950	543	*1010*	1850	821	*1510*	2750	1099	*2010*	3650	1377	*2510*	4550
−262	*−440*		−16.7	*2*	35.6	11.1	*52*	125.6	49	*120*	248	271	*520*	968	549	*1020*	1868	827	*1520*	2768	1104	*2020*	3668	1382	*2520*	4568
−257	*−430*		−16.1	*3*	37.4	11.7	*53*	127.4	54	*130*	266	277	*530*	986	554	*1030*	1886	832	*1530*	2786	1110	*2030*	3686	1388	*2530*	4586
−251	*−420*		−15.6	*4*	39.2	12.2	*54*	129.2	60	*140*	284	282	*540*	1004	560	*1040*	1904	838	*1540*	2804	1116	*2040*	3704	1393	*2540*	4604
−246	*−410*		−15.0	*5*	41.0	12.8	*55*	131.0	66	*150*	302	288	*550*	1022	566	*1050*	1922	843	*1550*	2822	1121	*2050*	3722	1399	*2550*	4622
−240	*−400*		−14.4	*6*	42.8	13.3	*56*	132.8	71	*160*	320	293	*560*	1040	571	*1060*	1940	849	*1560*	2840	1127	*2060*	3740	1404	*2560*	4640
−234	*−390*		−13.9	*7*	44.6	13.9	*57*	134.6	77	*170*	338	299	*570*	1058	577	*1070*	1958	854	*1570*	2858	1132	*2070*	3758	1410	*2570*	4658
−229	*−380*		−13.3	*8*	46.4	14.4	*58*	136.4	82	*180*	356	304	*580*	1076	582	*1080*	1976	860	*1580*	2876	1138	*2080*	3776	1416	*2580*	4676
−223	*−370*		−12.8	*9*	48.2	15.0	*59*	138.2	88	*190*	374	310	*590*	1094	588	*1090*	1994	866	*1590*	2894	1143	*2090*	3794	1421	*2590*	4694
−218	*−360*		−12.2	*10*	50.0	15.6	*60*	140.0	93	*200*	392	316	*600*	1112	593	*1100*	2012	871	*1600*	2912	1149	*2100*	3812	1427	*2600*	4712
−212	*−350*		−11.7	*11*	51.8	16.1	*61*	141.8	99	*210*	410	321	*610*	1130	599	*1110*	2030	877	*1610*	2930	1154	*2110*	3830	1432	*2610*	4730
−207	*−340*		−11.1	*12*	53.6	16.7	*62*	143.6	100	*212*	413.6	327	*620*	1148	604	*1120*	2048	882	*1620*	2948	1160	*2120*	3848	1438	*2620*	4748
−201	*−330*		−10.6	*13*	55.4	17.2	*63*	145.4	104	*220*	428	332	*630*	1166	610	*1130*	2066	888	*1630*	2966	1166	*2130*	3866	1443	*2630*	4766
−196	*−320*		−10.0	*14*	57.2	17.8	*64*	147.2	110	*230*	446	338	*640*	1184	616	*1140*	2084	893	*1640*	2984	1171	*2140*	3884	1449	*2640*	4784
−190	*−310*		− 9.4	*15*	59.0	18.3	*65*	149.0	116	*240*	464	343	*650*	1202	621	*1150*	2102	899	*1650*	3002	1177	*2150*	3902	1454	*2650*	4802
−184	*−300*		− 8.9	*16*	60.8	18.9	*66*	150.8	121	*250*	482	349	*660*	1220	627	*1160*	2120	904	*1660*	3020	1182	*2160*	3920	1460	*2660*	4820
−179	*−290*		− 8.3	*17*	62.6	19.4	*67*	152.6	127	*260*	500	354	*670*	1238	632	*1170*	2138	910	*1670*	3038	1188	*2170*	3938	1466	*2670*	4838
−173	*−280*		− 7.8	*18*	64.4	20.0	*68*	154.4	132	*270*	518	360	*680*	1256	638	*1180*	2156	916	*1680*	3056	1193	*2180*	3956	1471	*2680*	4856
−169	*−273*	−459.4	− 7.2	*19*	66.2	20.6	*69*	156.2	138	*280*	536	366	*690*	1274	643	*1190*	2174	921	*1690*	3074	1199	*2190*	3974	1477	*2690*	4874
−168	*−270*	−454	− 6.7	*20*	68.0	21.1	*70*	158.0	143	*290*	554	371	*700*	1292	649	*1200*	2192	927	*1700*	3092	1204	*2200*	3992	1482	*2700*	4892
−162	*−260*	−436	− 6.1	*21*	69.8	21.7	*71*	159.8	149	*300*	572	377	*710*	1310	654	*1210*	2210	932	*1710*	3110	1210	*2210*	4010	1488	*2710*	4910
−157	*−250*	−418	− 5.6	*22*	71.6	22.2	*72*	161.6	154	*310*	590	382	*720*	1328	660	*1220*	2228	938	*1720*	3128	1216	*2220*	4028	1493	*2720*	4928
−151	*−240*	−400	− 5.0	*23*	73.4	22.8	*73*	163.4	160	*320*	608	388	*730*	1346	666	*1230*	2246	943	*1730*	3146	1221	*2230*	4046	1499	*2730*	4946
−146	*−230*	−382	− 4.4	*24*	75.2	23.3	*74*	165.2	166	*330*	626	393	*740*	1364	671	*1240*	2264	949	*1740*	3164	1227	*2240*	4064	1504	*2740*	4964
−140	*−220*	−364	− 3.9	*25*	77.0	23.9	*75*	167.0	171	*340*	644	399	*750*	1382	677	*1250*	2282	954	*1750*	3182	1232	*2250*	4082	1510	*2750*	4982
−134	*−210*	−346	− 3.3	*26*	78.8	24.4	*76*	168.8	177	*350*	662	404	*760*	1400	682	*1260*	2300	960	*1760*	3200	1238	*2260*	4100	1516	*2760*	5000
−129	*−200*	−328	− 2.8	*27*	80.6	25.0	*77*	170.6	182	*360*	680	410	*770*	1418	688	*1270*	2318	966	*1770*	3218	1243	*2270*	4118	1521	*2770*	5018
−123	*−190*	−310	− 2.2	*28*	82.4	25.6	*78*	172.4	188	*370*	698	416	*780*	1436	693	*1280*	2336	971	*1780*	3236	1249	*2280*	4136	1527	*2780*	5036
−118	*−180*	−292	− 1.7	*29*	84.2	26.1	*79*	174.2	193	*380*	716	421	*790*	1454	699	*1290*	2354	977	*1790*	3254	1254	*2290*	4154	1532	*2790*	5054
−112	*−170*	−274	− 1.1	*30*	86.0	26.7	*80*	176.0	199	*390*	734	427	*800*	1472	704	*1300*	2372	982	*1800*	3272	1260	*2300*	4172	1538	*2800*	5072
−107	*−160*	−256	− 0.6	*31*	87.8	27.2	*81*	177.8	204	*400*	752	432	*810*	1490	710	*1310*	2390	988	*1810*	3290	1266	*2310*	4190	1543	*2810*	5090
−101	*−150*	−238	0.0	*32*	89.6	27.8	*82*	179.6	210	*410*	770	438	*820*	1508	716	*1320*	2408	993	*1820*	3308	1271	*2320*	4208	1549	*2820*	5108
− 96	*−140*	−220	0.6	*33*	91.4	28.3	*83*	181.4	216	*420*	788	443	*830*	1526	721	*1330*	2426	999	*1830*	3326	1277	*2330*	4226	1554	*2830*	5126
− 90	*−130*	−202	1.1	*34*	93.2	28.9	*84*	183.2	221	*430*	806	449	*840*	1544	727	*1340*	2444	1004	*1840*	3344	1282	*2340*	4244	1560	*2840*	5144
− 84	*−120*	−184	1.7	*35*	95.0	29.4	*85*	185.0	227	*440*	824	454	*850*	1562	732	*1350*	2462	1010	*1850*	3362	1288	*2350*	4262	1566	*2850*	5162
− 79	*−110*	−166	2.2	*36*	96.8	30.0	*86*	186.8	232	*450*	842	460	*860*	1580	738	*1360*	2480	1016	*1860*	3380	1293	*2360*	4280	1571	*2860*	5180
− 73	*−100*	−148	2.8	*37*	98.6	30.6	*87*	188.6	238	*460*	860	466	*870*	1598	743	*1370*	2498	1021	*1870*	3398	1299	*2370*	4298	1577	*2870*	5198
− 68	− 90	−130	3.3	*38*	100.4	31.1	*88*	190.4	243	*470*	878	471	*880*	1616	749	*1380*	2516	1027	*1880*	3416	1304	*2380*	4316	1582	*2880*	5216
− 62	− 80	−112	3.9	*39*	102.2	31.7	*89*	192.2	249	*480*	896	477	*890*	1634	754	*1390*	2534	1032	*1890*	3434	1310	*2390*	4334	1588	*2890*	5234
− 57	− 70	− 94	4.4	*40*	104.0	32.2	*90*	194.0	254	*490*	914	482	*900*	1652	760	*1400*	2552	1038	*1900*	3452	1316	*2400*	4352	1593	*2900*	5252
− 51	− 60	− 76	5.0	*41*	105.8	32.8	*91*	195.8				488	*910*	1670	766	*1410*	2570	1043	*1910*	3470	1321	*2410*	4370	1599	*2910*	5270
− 46	− 50	− 58	5.6	*42*	107.6	33.3	*92*	197.6				493	*920*	1688	771	*1420*	2588	1049	*1920*	3488	1327	*2420*	4388	1604	*2920*	5288
− 40	− 40	− 40	6.1	*43*	109.4	33.9	*93*	199.4				499	*930*	1706	777	*1430*	2606	1054	*1930*	3506	1332	*2430*	4406	1610	*2930*	5306
− 34	− 30	− 22	6.7	*44*	111.2	34.4	*94*	201.2				504	*940*	1724	782	*1440*	2624	1060	*1940*	3524	1338	*2440*	4424	1616	*2940*	5324
− 29	− 20	− 4	7.2	*45*	113.0	35.0	*95*	203.0				510	*950*	1742	788	*1450*	2642	1066	*1950*	3542	1343	*2450*	4442	1621	*2950*	5342
− 23	− 10	14	7.8	*46*	114.8	35.6	*96*	204.8				516	*960*	1760	793	*1460*	2660	1071	*1960*	3560	1349	*2460*	4460	1627	*2960*	5360
− 17.8	0	32	8.3	*47*	116.6	36.1	*97*	206.6				521	*970*	1778	799	*1470*	2678	1077	*1970*	3578	1354	*2470*	4478	1632	*2970*	5378
			8.9	*48*	118.4	36.7	*98*	208.4				527	*980*	1796	804	*1480*	2696	1082	*1980*	3596	1360	*2480*	4496	1638	*2980*	5396
			9.4	*49*	120.2	37.2	*99*	210.2				532	*990*	1814	810	*1490*	2714	1088	*1990*	3614	1366	*2490*	4514	1643	*2990*	5414



better do a little home-work on **ALLOYS**

The use of alloys has grown and is growing because the properties of metals for war purposes must go far beyond former requirements, and because alloying materials are now available in ever-increasing amounts, and because new metallurgical knowledge has improved the efficiency and the economy of employing such materials.

The end of the war will not reverse all this. In many quarters, rather, it will intensify competition and the urge to improve production at the lowest possible cost.

Molybdenum, Tungsten, and Boron have all been important to the war economy and each in its own way will be important to the economy of reconversion. The Molybdenum Corporation has prepared helpful information and advice on the most advanced applications of all these three much-discussed elements and the most approved techniques in using them. Correspondence is invited.

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MCA

Method of Identification of Inclusions in Iron and Steel

Originated by Wm. Campbell and G. F. Comstock (Proc. A.S.T.M., Vol. 23, p. 521) and Modified by C. R. Wohrman, Merrill Scheil and Miss M. Baeyertz

Polish Specimen Carefully so as to Preserve Inclusions and Project Magnified Image on Ground Glass by Arc or Equally White Light Without Color Screen

Gray or Black Inclusions

Etch 10 sec. with 10% nitric acid in alcohol

- **Strongly Attacked** — LIME COMPOUND from mold wash (rare)
- **Unattacked** — Etch 5 min. with 10% chromic acid in water (Be careful to observe that the polished surface is wetted by the solution)
  - **Weakly Attacked** (slightly pitted or darkened) — COMPOUND OXIDE: (a) either FeO with FeS in solution (usually accompanied by FeO-FeS EUTECTIC), or (b) FeO+MnO and other OXIDES in solution. Note 1: Octahedral crystals are probably MAGNETITE. Note 2: Both (a) and (b) will be darkened further by 20 sec. sulphur printing (2% H_2SO_4 in water) and destroyed by etching with stannous chloride as indicated below
  - **Attacked** — FeS-MnS, rich in MnS. Note: Reaction not always decisive. Any unattacked FeS-MnS will be blackened by next treatment
    - **Completely Blackened** — (1*) FeS-MnS, MnS below 50% (2*) FeS-MnS, MnS above 50% or OXIDE very rich in MnO. * Refer to color before etch
    - **Partly Attacked** — (a) OXIDE rich in MnO (will be destroyed by stannous chloride) (b) SILICATE with some MnO (will be destroyed by hydrofluoric acid)
    - **Unattacked** (or partly attacked in previous treatments) — etch 10 min. with a saturated solution of stannous chloride in alcohol
      - **Attacked** — IRON OXIDE or (if previously pitted) COMPOUND OXIDE
      - **Unattacked** (or previously pitted) — etch 10 min. with 20% aqueous solution of hydrofluoric acid.
        - **Attacked** — SILICATE (if previously pitted presence of Mn is indicated)
        - **Unattacked** — Repolish and note color and form
          - If fine particles, very dark color, difficult to polish without pitting and not elongated by hot work is ALUMINA
          - If color not especially dark, easily polished smooth without pitting
            - Fairly large angular fragments, showing changeable bright spots as focus is changed, are SAND GRAINS (in steel castings)
            - Small angular particles, bluish in color probably TITANIUM OXIDE (in titanium treated steels)
  - **Unattacked** — Note color: (1) Very faint pale grey, (2) Medium or dark grey, and etch 5 min. with boiling alkaline sodium picrate

Inclusions of Warm Colors

Etch 10 min. with boiling alkaline sodium picrate

- **Attacked** — IRON SULPHIDE (pale yellowish)
- **Unattacked** — Etch 10 min. in 20% aqueous solution of HF
  - **Attacked:** Removes ZIRCONIUM NITRIDE (yellow cubes) and ZIRCONIUM SULPHIDE (tan crystals)
  - **Unattacked** Inclusions in high chromium steels — Etch 5 min. in boiling 10% H_2SO_4 + 1% $KMnO_4$, & lightly repolish*
    - **Unattacked** — CHROMIUM OXIDE (purplish gray by reflected light, bright green by transmitted light) TITANIUM NITRIDE (yellow cubes) TITANIUM CYANO-NITRIDE (pinkish; strongly angular, easily pitted in polishing)
    - **Attacked** — CHROMITE $Cr_2O_3 \cdot FeO$, isotropic; red to brown by transmitted light

* Note: Suitable only for stainless steels with clean (unoxidized) surfaces.

Supplementary Tests

In all instances check determinations in the light of the evidence of a careful chemical analysis, and, whenever possible, by other methods, such as:

I Sulphur Printing

(for 20 sec. using a 2% aqueous solution of H_2SO_4)
(1) Dissolves all FeS-MnS inclusions
(2) Partly dissolves (pits) FeO containing FeS and OXIDES of other metals in solution
(3) Leaves unchanged: IRON SULPHIDE (pale yellow), pure IRON OXIDE (medium grey), SILICATES (dark grey)

II Matweieff's Tests

(a) Dilute tartaric acid does not attack OXIDES or SILICATES, but colors MnS lightly and FeS decidedly
(b) Heat sample in hydrogen at 1600°F., OXIDES are reduced, SILICATES and SULPHIDES are unaffected
(c) Repolish (b), etch with dilute $FeCl_3$ in alcohol; if reduced oxide particles are colored deeply they contain some Mn

III Rohl's Test for Sulphides

Short etch with 1% picric acid in alcohol, then temper to dark yellow. FeS turns dark blue to reddish violet, and MnS turns dull grey to bright white.

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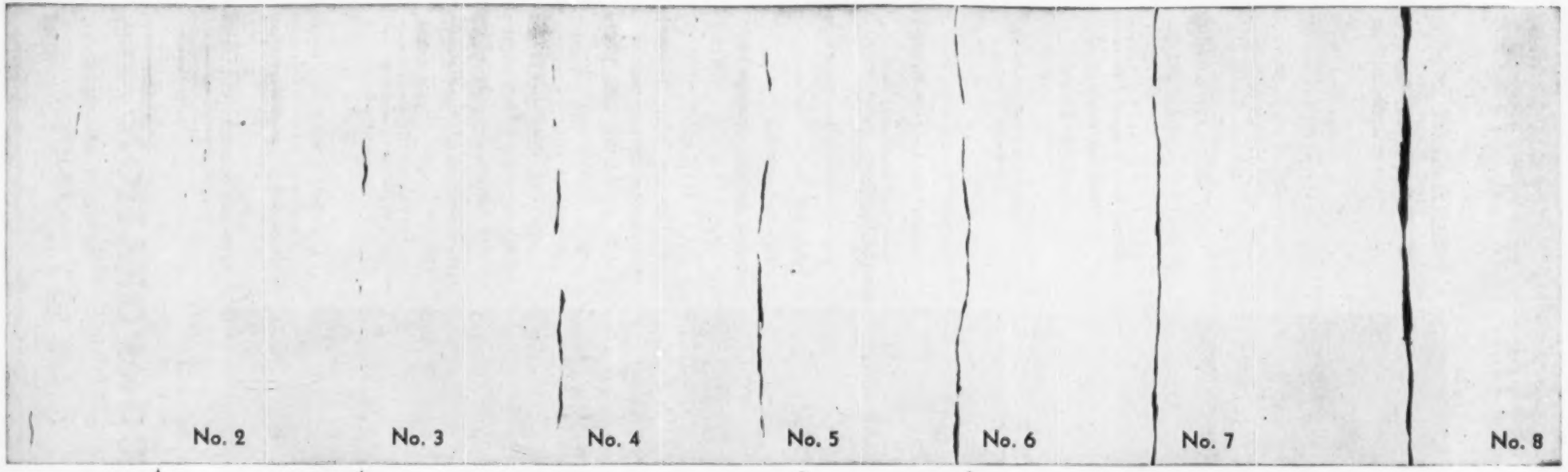
Rating of Inclusions ("Dirt Chart")

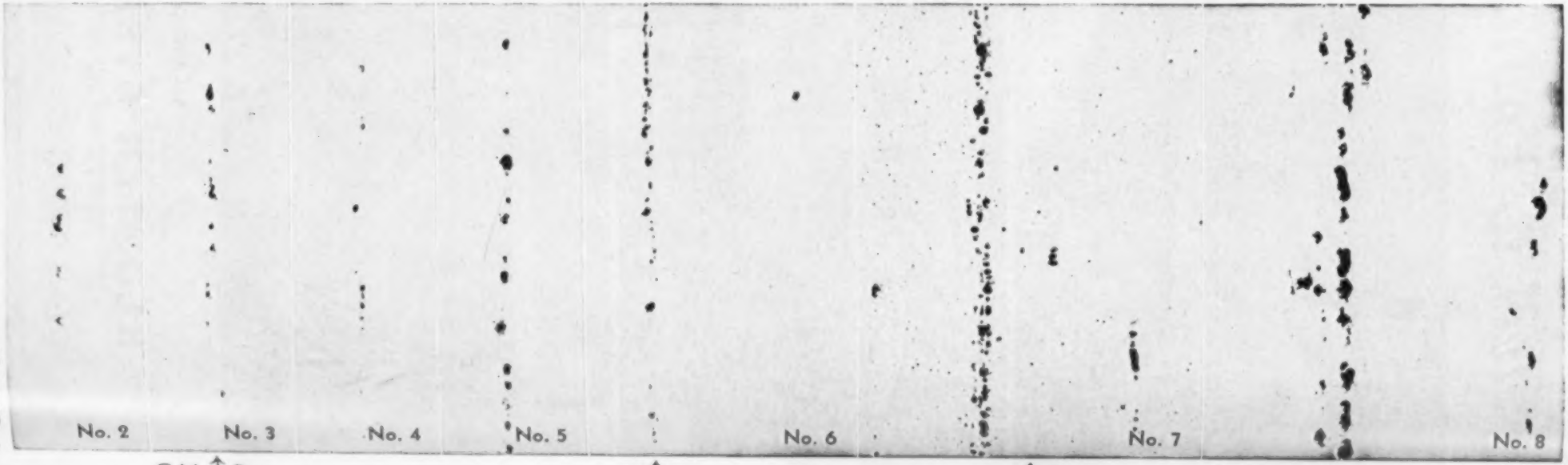
In use by Chevrolet Motor Co. *Developed by George W. Walker*

(General Motors Standards Book shows four types, A to D, of each variety as indicated in this style of type.)



G.M. ↑ A G.M. ↑ B **Silicate Slag Inclusions** G.M. ↑ C G.M. ↑ D, except that stringers are fragmented

←G.M. Type A shows scattered small inclusions→



G.M. ↑ B G.M ↑ C **Oxide Inclusions** G.M. ↑ D

All micros at 100 diameters

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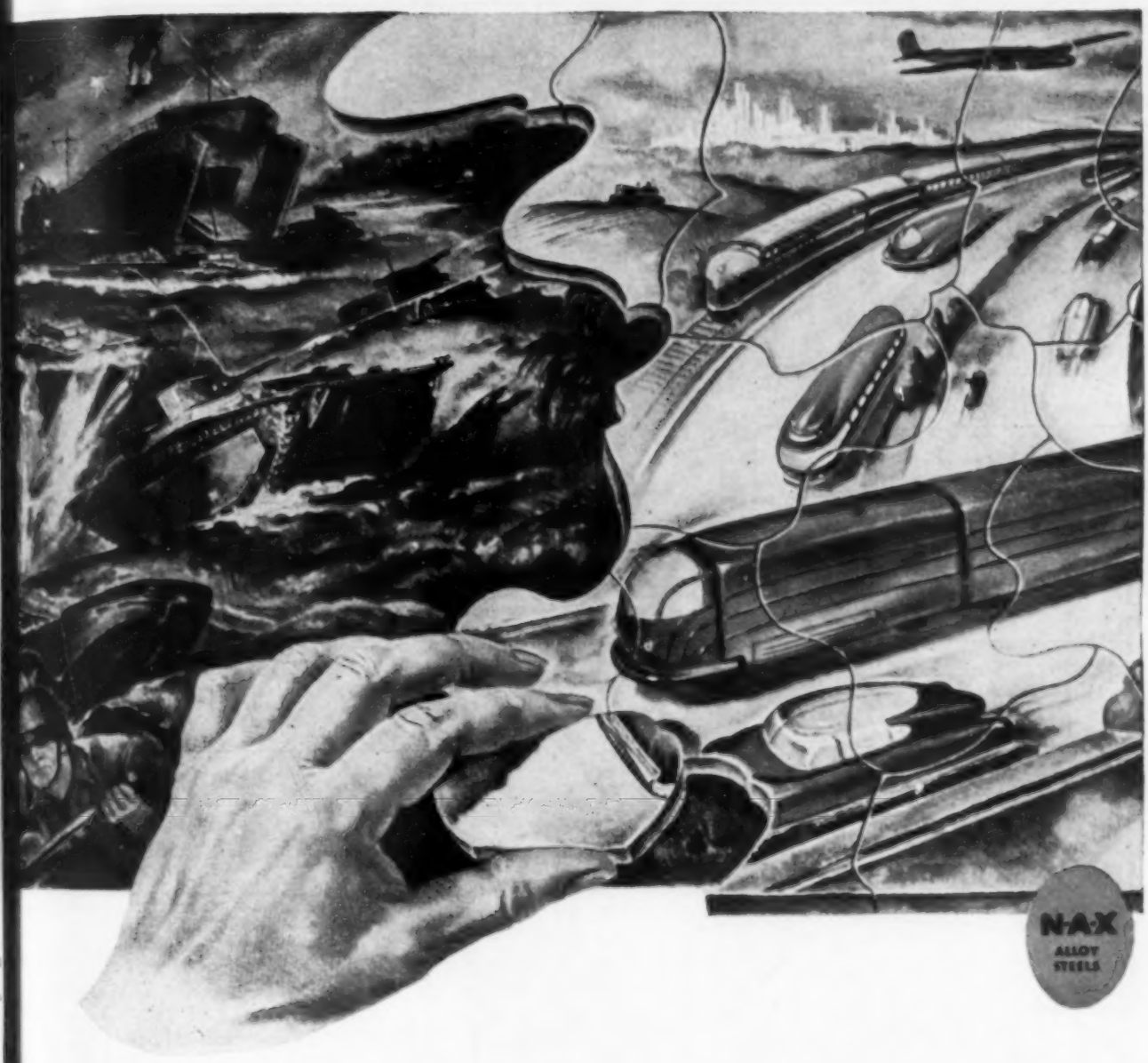
Specific Effects of Alloys in Steel

Element	Solid Solubility		Influence Upon Ferrite	Influence Upon Austenite (Hardenability)	Influence Exerted Through Carbide		Principal Functions
	In Gamma Iron	In Alpha Iron			Carbide Forming Tendency	Action During Tempering	
Aluminum Al	1.1% (Increased by C)	30% ±	Hardens considerably by solid solution	Increases hardenability mildly, if dissolved in austenite	Less than Fe (Graphitizes)	.....	1. Deoxidizes efficiently. 2. Restricts grain growth (by forming dispersed oxides or nitrides) 3. Alloying element in nitriding steel
Chromium Cr	12.8% (20% with 0.5% C)	Unlimited	Hardens slightly; increases corrosion resistance	Increases hardenability moderately, similarly to manganese	Greater than Mn; Less than W	Mildly resists softening	1. Increases corrosion and oxidation resistance 2. Increases hardenability 3. Adds some strength at high temperatures 4. Resists abrasion and wear (with high carbon)
Cobalt Co	Unlimited	80% ±	Hardens considerably by solid solution	Decreases hardenability as dissolved	Similar to Fe	Sustains hardness by solid solution	1. Contributes to red hardness by hardening ferrite
Manganese Mn	Unlimited	15 to 18%	Hardens markedly; reduces plasticity somewhat	Increases hardenability moderately, similarly to chromium	Greater than Fe; Less than Cr	Very little, in usual percentages	1. Counteracts brittleness from the sulphur 2. Increases hardenability inexpensively 3. Forms batter resistant steel (high Mn, high C)
Molybdenum Mo	3% ± (8% with 0.3% C)	32%, (Less with lowered temperature)	Provides age-hardening system in high Mo-Fe alloys	Increases hardenability strongly (Mo > Cr)	Strong; Greater than Cr	Opposes softening, by secondary hardening	1. Raises coarsening temperature of austenite 2. Deepens hardening 3. Raises hot and creep strength, red hardness 4. Enhances corrosion resistance in stainless 5. Forms abrasion-resisting particles
Nickel Ni	Unlimited	25% ± (Irrespective of carbon content)	Strengthens and toughens by solid solution	Increases hardenability mildly, but tends to retain austenite with higher carbon	Less than Fe (Graphitizes)	Very little in small percentages	1. Strengthens unquenched or annealed steels 2. Toughens pearlitic-ferritic steels (especially at low temperature) 3. Renders high chromium-iron alloys austenitic
Phosphorus P	0.5%	2.5% (Irrespective of carbon content)	Hardens strongly by solid solution	Increases hardenability, similarly to manganese	Nil	.....	1. Strengthens low carbon steel 2. Increases resistance to corrosion 3. Improves machinability in free-cutting steels
Silicon Si	2% ± (9% with 0.35% C)	18.5%, (Not much changed by carbon)	Hardens with loss in plasticity (Mn < Si < P)	Increases hardenability more than nickel (Ni < Si < Mn)	Negative (Graphitizes)	Sustains hardness by solid solution	1. Used as general purpose deoxidizer 2. Alloy for electrical and magnetic sheet 3. Improves oxidation resistance 4. Increases hardenability of steels carrying non-graphitizing elements 5. Strengthens low alloy steels
Titanium Ti	0.75% (1% ± with 0.20% C)	6% ±, (Less with lowered temperature)	Provides age-hardening system in high Ti-Fe alloys	Probably increases hardenability very strongly, *as dissolved*. Its carbide effects reduce hardenability	Greatest known (2% Ti renders 0.50% carbon steel unhardenable)	Persistent carbides probably unaffected. Some secondary hardening	1. Fixes carbon in inert particles (a) Reduces martensitic hardness and hardenability in medium chromium steels (b) Prevents formation of austenite in high chromium steels (c) Prevents localized depletion of chromium in stainless during long heating
Tungsten W	6% (11% with 0.25% C)	32%, (Less with lowered temperature)	Provides age-hardening system in high W-Fe alloys	Increases hardenability strongly in small amounts	Strong	Opposes softening by secondary hardening	1. Forms hard, abrasion resistant particles in toolsteels 2. Promotes red hardness and hot strength
Vanadium V	1.5% ± (4% with 0.20% C)	Unlimited	Hardens moderately by solid solution	Increases hardenability very strongly, *as dissolved*	Very strong (V < Ti or Cb)	Maximum for secondary hardening	1. Elevates coarsening temperature of austenite (promotes fine grain) 2. Increases hardenability (when dissolved) 3. Resists tempering and causes marked secondary hardening

Revised, 1942. Adapted from "The Functions of the Alloying Elements in Steel" by Edgar C. Bain; published by [illegible]

A new picture is forming



hat popular dream of tomorrow's tter world is not all fantasy. Many ctors that must shape it are already tablished—they are fitting themves together, bit by bit, in an unistakable pattern.

Various war perfected materials, for stance, will inevitably change the merican scene. Take N-A-X HIGH NSILE for example. Its amazing strength and toughness will certainly mean lighter weight, less bulky, more durable products of peace—more efficient, more economical planes, trains and motor vehicles—better, less expensive furniture, home appliances and other everyday items that will form our future.

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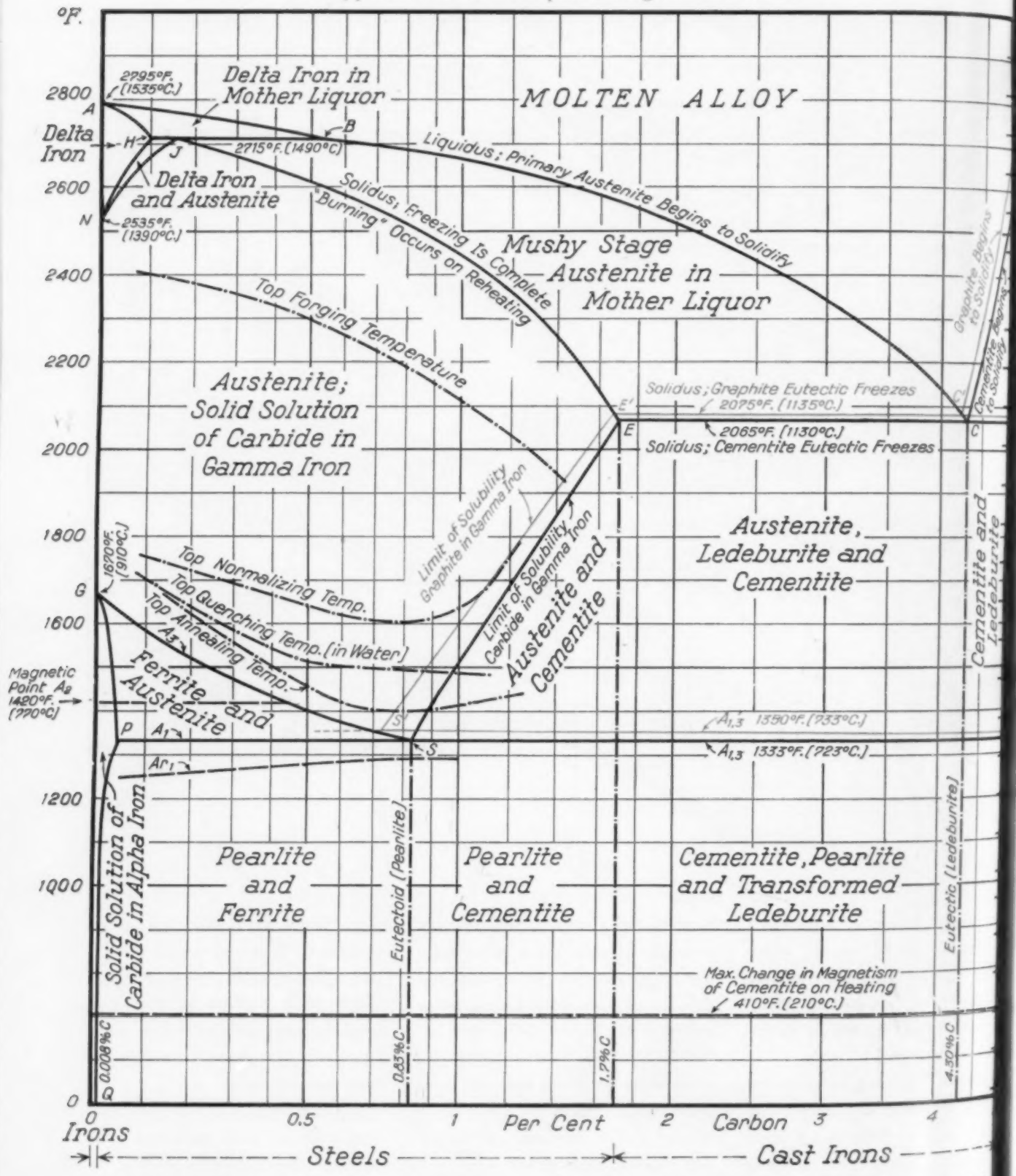
Iron, Iron Carbide Equilibrium Diagram

Approximate Iron-Graphite Diagram in Red



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Ar1 according to Hoyt and Dowdell, "Metals and Common Alloys," for cooling rates of 1° C. in 3 sec.

Line GPQ according to J. H. Whiteley, *Journal* Iron and Steel Institute, 1936.

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***EACH** of these steels assures you of Latrobe's distinctive qualities — superior heat-treating properties and longer tool life. Each is ideally adapted to its particular use.*

DOUBLE-SIX

C	Cr	W	Mo	V
.84	4.15	6.23	5.10	1.85

TATMO

C	Cr	W	Mo	V
.79	3.96	1.55	8.30	1.15

T.N.W.

C	Cr	W	Mo	V
88	3.90	—	8.00	1.90

HV-6

C	Cr	W	Mo	V
1.15	4.10	6.15	6.15	3.10

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5

Properties of Important Wrought Chromium-Iron Alloys

Revised 1943, from data furnished by U.S. Steel Corp., Electro Metallurgical Co., and Commitee A-10, A.S.T.M.

Nominal Alloy A.I.S.I. Type No.	2% Cr —	5% Cr 502		9% Cr —	12% Cr 410:416		Cutlery 420		17% Cr 430		27% Cr 446	
Chemical composition												
Chromium	1.75 to 2.25	4 to 6		8 to 10	10 to 14		12 to 14		16 to 18		23 to 27	
Molybdenum	0.6	0.5		1.0 or 1.5	(0.6 max.)		—		(0.5 max. Ni)		(1.0 max. Ni)	
Mn (max.)	0.65	0.50		0.5	0.5		0.55		0.5		1.5	
Carbon	0.15 max.	0.10 to 0.20		0.15 max.	0.15 max.		0.30 to 0.40		0.12 max.		0.35 max.	
Specific gravity												
Lb. per cu. in.	—	0.28		0.282	0.28		0.278		0.277		0.273	
(Mild steel = 1.00)	—	0.99		1.00	0.98		0.98		0.98		0.96	
Resistance at 70°F.												
Microhms per cm³	—	35		—	57		60		60		67	
(Mild steel = 1.00)	—	3.2		—	5.2		5.5		5.5		6.1	
Melting range, °F.												
Top	—	2800		—	2790		2750		2750		2750	
Bottom	—	2700		—	2700		2580		2700		2700	
Structure (normal)	Pearlitic	Martensitic		Martensitic	Martensitic or Ferritic		Martensitic		Ferritic		Ferritic	
Magnetism												
Ferromagnetic	Yes	Yes		Yes	Yes		Yes		Yes		Yes	
Permeability: As annealed	—	—		—	—		—		—		—	
Permeability: Cold worked 10%	—	—		—	—		—		—		—	
Specific heat												
C.g.s. units, 0 to 100°C.	0.11	0.11		0.11	0.11		0.117		0.11		0.12	
(Mild steel = 1.00)	1.0	1.0		1.0	1.0		1.1		1.0		1.1	
Thermal conductivity												
*C.g.s. units at 100°C.	—	0.0874		—	0.0595		0.054		0.0595		0.0500	
(Mild steel = 1.00)	—	0.73		—	0.50		0.45		0.50		0.42	
C.g.s. units at 500°C.	—	0.0804		—	0.0686		—		0.0624		0.0581	
Thermal expansion per °F. x 1,000,000												
From 32 to 212°F.	—	6.2		6.2	6.1		5.7		5.6		5.9	
(Mild steel = 1.00)	—	0.94		0.94	0.93		0.87		0.86		0.90	
From 32 to 932°F.	7.3	7.2		6.9	6.7		6.6		6.7		6.3	
Mechanical Properties at Room Temperature	Annealed	Annealed	Quenched (1600°); Tempered (1000°)	Annealed	Annealed	Quenched & Tempered (800-1300°)	Annealed	†† Heat Treated	Annealed	Cold Worked (Wire)	Annealed	Cold Worked (Wire)
Tensile strength, 1000 psi.	60 to 70	65 to 85	175	70 to 87	65 to 85	90 to 180	90	230 to 260	70 to 80	90 to 110	75 to 95	85 to 175
Yield strength, 1000 psi.	30 to 45	30 to 60	145	35 to 45	35 to 45	70 to 160	65	200 to 220	40 to 50	80	50 to 60	55 to 155
Elastic modulus, 10^6 psi.	29	29	—	29	29	29	29	—	29	—	29	—
Elongation, % in 2 in.	40 to 30	45 to 35	17	40 to 25	35 to 25	25 to 15	27	5	30 to 25	25 to 8	30 to 20	25 to 2
Reduction of Area, %	65 to 45	75 to 60	60	70 to 50	65	65 to 45	59	7	75 to 50	70	60 to 50	55 to 25
Impact, ft-lb., Charpy	35 to 65	45 to 75	—	45	—	—	—	—	—	—	—	—
Izod	—	75 to 85	32	90	100 to 60	20 to 30	65	—	—	—	2	—
Fatigue endurance limit, 1000 psi.	—	—	—	—	43	55	50	—	34	50	50	—
Hardness, Brinell	130 to 160	135 to 180	300	145 to 180	135 to 165	180 to 380	190	480	175	197	160 to 190	150 to 250
Rockwell	—	B 75 to 85	C 24	—	B 80	—	B 90	C 54	B 80	B 97	B 85	C 0 to 25
Erichsen value, mm.	—	—	—	—	7 to 8	—	—	—	7 to 9	—	—	—
Olsen value, lb.	—	0.375 to 0.450	—	—	—	—	—	—	—	—	—	—
Stress in psi. causing 1% "creep" in 10,000 hr. at 1000°F.	11,000	9,000		11,000	12,000		4,500		8,500		6,200	
Stress in psi. causing 1% "creep" in 10,000 hr. at 1100	5,500	4,500		6,950	4,700		1,700		5,000		3,000	
Stress in psi. causing 1% "creep" in 10,000 hr. at 1200	3,000	2,100		2,400	2,200		1,300		2,100		1,600	
Stress in psi. causing 1% "creep" in 10,000 hr. at 1350	—	—		—	1,400				1,000		400	
Scaling temp., °F.	1100	1,150		1200	1,250		1,250		1,550		2,000	
Initial forging temp., °F.	2200	2,100 to 2200		2,000 to 2,150	2,000 to 2,100		2,000 to 2,100		1,900 to 2,050		1,900 to 2,000	
Finishing temp., °F.	1500	1,500 to 1,600		1600	1,500		1,700 to 1,750		1,500		1,300 to 1,450	
Annealing treatment	†	†††		***	**		Cool from 1,450 to 1550		Air cool from 1,400 to 1,450		Rapid cool from 1,450 to 1,550	

* Thermal conductivity is measured as calories per sq. cm. per sec. per °C. per cm.

†† Oil quenched from 1850°F. and tempered

** Furnace cool from 1550 to 1100°F., or air cool from long heat at 1250 to 1350°F.

*** Cool from 1325 to 1375°F. or slow cool from 1600 to 1675°F.

††† -"- -"- -"- -"- -"- -"- -"- -"- -"- 1525 to 1600°F.

† Furnace cool from 1620°F.

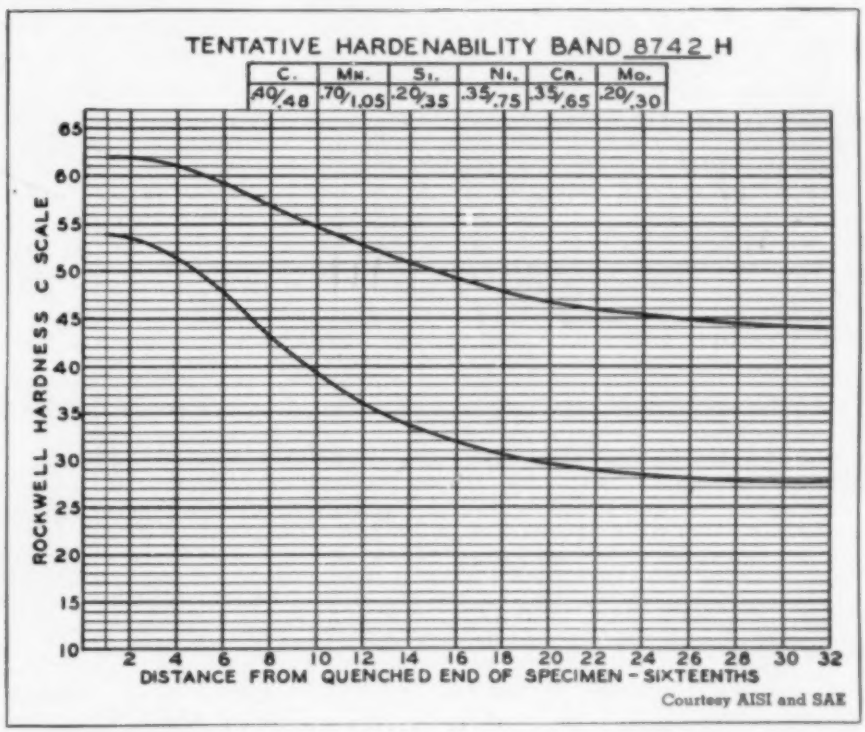
Now... You can buy Alloy Steel to BAND HARDENABILITY

To avoid quenching cracks and at the same time insure a thoroughly effective quench and maintain specified physicals, more and more engineers are finding it desirable to order alloy steel to maximum and minimum hardenability ranges.

These maximum-minimum ranges, based on standard end-quench hardenability tests, have been charted for some 4100, 4300, 4600, 8600, and 8700 types of steel, and acceptable figures are now available in booklet form.* Each chart is based on a study of many heats representative of the entire steel industry.

The practical value of band hardenability is best illustrated by a specific example, as follows:

Suppose your experience has indicated that a 1½-inch round, oil-quenched, must show center hardness between Rockwell C 45 and C 58 to successfully pass manufacturing operations. A check of standard hardenability curves at approximately the 7/16-inch point will show that Analysis 8742H (H for hardenability) is the one to order.



Courtesy AISI and SAE

BETHLEHEM metallurgists have had an active part in the standardization of maximum-minimum hardenability values established for the industry. Our technicians will be glad to work with you and your staff on practical applications of these findings.

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BETHLEHEM, PA.

Bethlehem Steel Export Corporation
New York City

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BETHLEHEM STEEL ★

*"Contributions to the Metallurgy of Steel, No. 11," published by the American Iron and Steel Institute and the Society of Automotive Engineers.

Properties of Important Wrought Chromium-Nickel-Iron Alloys

Revised 1943, from data furnished by U.S. Steel Corp., Electro Metallurgical Co., and Commitee A-10, A.S.T.M.

Nominal Alloy A.I.S.I. Type No.	18-8 302†	18-8 Ti 321	18-8 Cb 347	18-12 Mo 316	20-12 308	24-12 309	25-20 310	18-26 311
Chemical composition								
Chromium	17 to 19	17 to 19	17 to 19	16 to 18	19-22	22 to 24	24 to 26	18 to 20
Nickel	8 to 10††	8 to 11	9 to 12	10 to 14	10-12	12 to 15	19 to 22	24 to 26
Mn (max.)	1.25	2.00	2.00	2.50	2.00	2.00	2.00 max.	2.00 max.
Carbon	0.08 to 0.20	0.10 max.	0.10 max.	0.10 max.	0.10 max.	0.20 max.	0.25 max.	0.25 max.
Others	—	Ti 4 x C	Cb 10 x C	2 to 3 Mo	—	—	—	—
Specific gravity								
Lb. per cu. in.	0.288	0.286	0.29	0.291	0.287	0.29	0.285	0.280
(Mild steel = 1.00)	1.02	1.01	1.02	1.03	1.01	1.01	1.01	0.99
Electrical resistance at 70°F.								
Microhm per cm.³	72*	72	73	74	—	78	80 ±	102
(Mild steel = 1.00)	6.6	6.6	6.7	6.8	—	7.1	7.3	9.3
Melting range, °F.								
Top	2590	2600		2550	2590	2650	2650	—
Bottom	2550	2550		2500	2550	2550	2550	—
Structure	Austenitic	Austenitic		Austenitic	Austenitic	Austenitic	Austenitic	
Magnetism								
Ferromagnetic	—	—	—	—	—	—	Trace	—
Permeability: As annealed	1.003	1.003	1.02	1.003	—	1.003	1.003	—
Permeability: Cold Worked	1.10 to 2.0	—	—	1.10 to 10.0	—	—	—	—
Specific heat								
C.g.s. units, 0 to 100°C.	0.12	0.12		0.12	—	0.12	0.14	—
(Mild steel = 1.00)	1.1	1.1		1.1	—	1.1	1.3	—
Thermal conductivity								
**C.g.s. units at 100°C.	0.0388	0.0385		0.0372	0.039	0.03 to 0.04	0.0330	—
(Mild steel = 1.00)	0.33	0.32		0.316	0.33	0.25 to 0.35	0.280	—
C.g.s. units at 500°C.	0.0512	0.0528		0.0499	—	—	0.0413	—
Thermal expansion per °F. x 1,000,000								
From 32 to 212°F.	9.5	9.3		8.9	9.6	8.3	8.0	8.8
(Mild steel = 1.00)	1.44	1.40		1.35	1.45	1.26	1.21	1.33
From 32 to 932°F.	10.2	10.2		9.7	—	9.6	9.2	9.3

Mechanical Properties at Room Temperature	Annealed	Cold Worked (Type 301 X)†	Annealed	Annealed	Cold Worked	Annealed	Annealed	Cold Worked	Annealed	Annealed
Tensile strength, 1000 psi.	80 to 100	150 to 300	75 to 95	80 to 95	140 to 200	70 to 90	90 to 100	110 to 220	80 to 110	90 to 110
Yield strength, 1000 psi.	30 to 45	130 to 275	30 to 45	35	120 to 180	30 to 60	40	65 to 230	35 to 55	45 to 50
Elastic modulus, 10^6 psi.	28	26 to 28	29	28	—	28	29	—	30	30†
Elongation, % in 2 in.	65 to 45	20 to 2	60 to 45	65 to 50	18 to 6	75 to 50	55 to 35	15 to 3	60 to 45	35 to 30
Reduction of area, %	70 to 50	55 to 10	65 to 50	70 to 55	65	70 to 45	60 to 50	55 to 20	60 to 50	45 to 35
Impact, ft-lb.; Charpy	90 to 60	—	80	80	—	—	90 to 60	—	80 to 70	—
Izod	110 to 75	50 to 20	100	100	—	—	—	—	100 to 60	50 to 90
Fatigue endurance limit, 1000 psi.	30 to 40	85	45	39	—	—	42	—	—	—
Hardness, Brinell	150 to 160	365 to 410	135 to 149	135 to 165	—	135 to 185	150 to 185	170 to 375	160	160 to 185
Rockwell	B-75 to 80	C-36 to 50	B-75	B-75 to 90	C-30 to 38	—	B-80 to 90	C-5 to 40	B-80	—
Erichsen value, mm.	10 to 14	—	12	12	—	—	7 to 8	—	—	—

Stress in psi. causing 1% "creep" in 10,000 hr. at	321	347						
1000°F.	17,000	18,000	19,000	23,000			17,000	17,000	17,000
1200	7,000	7,800	9,500	10,000			8,500	9,000	—
1350	2,500	3,600	4,000	5,500			3,500	3,300	—
1500	850	850	—	2,000			1,000	1,100	—
1600	—	—	—	—			—	—	1,900

Scaling temp., °F.	1650	1650	1650	1650	2000	2000	1650
Initial forging temp., °F.	2000 to 2200	2100 to 2200	2100 to 2200	—	2000 to 2150	2000 to 2150	2050
Finishing temp., °F.	Not under 1700	Same as 18-8	As for 18-8	—	Not under 1800	1800 to 1850	1700
Annealing treatment	Heat at 1950 to 2050°F. and Quench	Same as 18-8	1950 to 2050°F. and Quench	—	Heat at 2000 to 2100°F. and Quench	Same as for 24-12	2000°+ Quick Heat & Quench

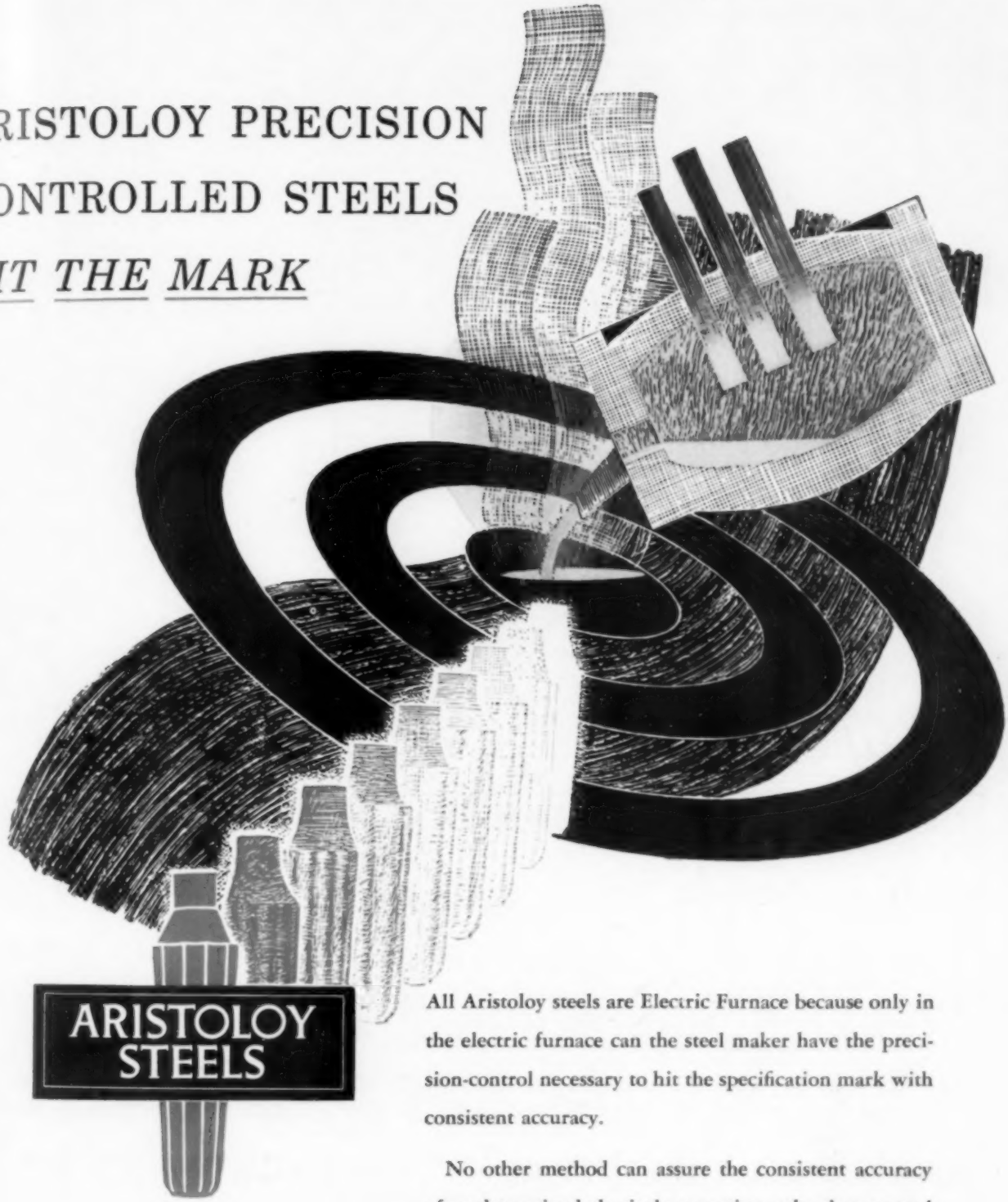
* Electrical resistance of cold worked 18-8 ranges from 70 to 82 microhms per cm cube

** Thermal conductivity is measured as calories per sq. cm. per sec. per °C. per cm.

† Type 301 X is the cold-worked sheet for light weight structure

†† For spinning purposes Ni is sometimes specified 10 to 12 %

ARISTOLOY PRECISION CONTROLLED STEELS *HIT THE MARK*



All Aristoloy steels are Electric Furnace because only in the electric furnace can the steel maker have the precision-control necessary to hit the specification mark with consistent accuracy.

No other method can assure the consistent accuracy of predetermined physical properties or the close control of chemical analyses.

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STAINLESS STEELS · BEARING QUALITY STEELS

The Chemical Elements and Their Discoverers

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Courtesy Fisher Scientific Co.

Name	Isotopes	At. No.	Valence	At. Wt.	Discoverer and Nationality	Year
Actinium (Ac)		89	3	228	Debierne (F)	1899
Alabamine		85	8		Allison, Murphy (A)	1931
Aluminum (Al)	1	13	3	26.97	Örsted (Da)	1825
Antimony (Sb) (*Stibnium*)	2	51	3–5	121.76	Tholde (G)	1450
Argon (A)	2	18	0–8	39.944	Raleigh, Ramsay (E)	1894
Arsenic (As)	1	33	3–5	74.91	Albertus Magnus (R)	1250
Barium (Ba)	4	56	2	137.36	Davy (E)	1808
Beryllium (Be) (*Glucinum*)	2	4	2	9.02	Vauquelin (F)	1798
Bismuth (Bi)	2	83	3–5	209.00	Geoffroy (E)	1753
Boron (B)	2	5	3	10.82	Davy (E), Gay-Lussac (F) Thenard (F)	1808
Bromine (Br)	2	35	1–7	79.916	Balard (F)	1826
Cadmium (Cd)	6	48	2	112.41	Stromeyer (G)	1817
Calcium (Ca)	2	20	2	40.08	Davy (E), Berzelius (S), Pontin (F)	1808
Carbon (C)	2	6	2–4	12.000	Ancient	B.C.
Cerium (Ce)	2	58	3–4	140.13	Klaproth (G), Hissinger, Berzelius (S)	1803
Cesium (Cs)	1	55	1	132.91	Bunsen, Kirchoff (G)	1860
Chlorine (Cl)	2	17	1–7	35.457	Scheele (S)	1774
Chromium (Cr)	4	24	2–3–6	52.01	Vauquelin (F)	1798
Cobalt (Co)	1	27	2–3	58.94	Brandt (S)	1735
Columbium (Cb) (*Niobium*)		41	3–5	92.91	Hatchett (E)	1801
Copper (Cu) (*Cuprum*)	2	29	1–2	63.57	Ancient	B.C.
Dyprosium (Dy)		66	3	162.46	Boisbaudran (F)	1886
Erbium (Er)		68	3	167.64	Mosander (S)	1843
Europium (Eu)		63	3	152.00	Demarcay (F)	1901
Fluorine (F)	1	9	1–7	19.00	Scheele (S)	1771
Gadolium (Gd)		64	3	157.30	Marignac (F)	1880
Gallium (Ga) (*Gallia*)	2	31	3	69.72	Boisbaudran (F)	1875
Germanium (Ge) (*Germania*)	8	32	4	72.60	Winkler (G)	1886
Gold (Au) (*Aurum*)		79	1–3	197.2	Ancient	B.C.
Hafnium (Hf) (*Hafnia, Copenhagen*)		72	4	178.6	Coster (D), Hevesy (H)	1923
Helium (He) (*Helios*)	1	2	0–8	4.002	Janssen (F), Lockyer (E) Ramsay (E), Cleve (S)	1868 1895
Holmium (Ho) (*Holmia, Stockholm*)		67	3	163.5	Cleve (S)	1879
Hydrogen (H) (*Gr. Hydro*)	2	1	1	1.0078	Cavendish (E)	1766
Illinium (Il)		61	3–0		Hopkins, Yntema, (A), Harris, (C)	1926
Indium (In)	1	49	3	114.76	Reich, Richter (G),	1863
Iodine (I) (*Iodes*)	1	53	1–7	126.932	Courtois (F)	1811
Iridium (Ir) (*Iris, Rainbow*)		77	3–4	193.1	Tennant (E)	1804
Iron (Fe) (*Ferrum*)	2	26	2–3	55.84	Ancient	B.C.
Krypton (Kr) (*Gr. Kryptos, hidden*)	6	36	0–8	83.7	Ramsay, Travers (E)	1898
Lanthanum (La) (*Gr. Lanthano, to conceal*)	1	57	3	138.90	Mosander (S)	1839
Lead (Pb) (*Plumbum*)	8	82	2–4	207.22	Ancient	B.C.
Lithium (Li) (*Lithos, stone*)	2	3	1	6.940	Arfvedson (S)	1817
Lutecium (Lu) (*Lutetia, Paris*)		71	3	175.20	Urbain (F)	1907
Magnesium (Mg.) (*Magnesia, in Thessaly*)	3	12	2	24.32	Davy (E)	1808
Manganese (Mn) (*Magnes, magnet*)	1	25	2–4–6–7	54.93	Gahn (S)	1774
Masurium (Ma) (*Masurian, in Germany*)		43	7	96 (?)	Noddack, Tacke, Berg (G)	1924
Mercury (Hg) (*Hydrargyrum*)	7	80	1–2	200.61	Ancient	B.C.
Molybdenum (Mo) (*Gr. Molybdos, lead*)	7	42	3–4–6	96.0	Hjelm (S)	1781
Neodymium (Nd) (*Gr. Neos, New; Didymos, Twin*)	4	60	3	144.27	Welsbach (G)	1885

Name	Isotopes	At. No.	Valence	At. Wt.	Discoverer and Nationality	Year
Neon (Ne) (*Gr. Neos, New*)	3	10	0–8	20.183	Ramsey, Travers (E)	1898
Nickel (Ni)	3	28	2–3	58.69	Cronstedt (S)	1754
Nitrogen (N)	2	7	3–5	14.008	Rutherford (E)	1772
Osmium (Os) (*Gr. Osme, Color*)	6	76	2–3–4–8	191.5	Tennant (E)	1804
Oxygen (O)	3	8	2	16	Priestly (E)	1774
Palladium (Pd) (*Planet, Pallus*)		46	2–4	106.7	Wollaston (E)	1803
Phosphorus (P) (*Gr. Light Bearer*)	1	15	3–5	31.02	Brand (G)	1669
Platinum (Pt) (*Sp. platina*)		78	2–4	195.23	Wood (E)	1741
Polonium (Po)		84	6		Marie and Pierre Curie (F)	1898
Potassium (K) (*Kalium*)	2	19	1	39.10	Davy (E)	1807
Praseodymium (Pr) (*Gr. praseos, Green; didymos, Twin*)	1	59	3	140.92	Welsbach (G)	1885
Protoactinium (Pa)		91	5		Soddy, Cranston (E), Hahn, Meitner (G)	1917
Radium (Ra) (*Radius, ray*)	4	88	2	225.97	Marie and Pierre Curie (F)	1898
Radon (Rn) (*Niton*)		86	0–8	222.00	Dorn (G)	1900
Rhenium (Re) (*Rhine prov.*)	2	75	7	186.31	Noddack, Tacke, Berg (G)	1924
Rhodium (Rh) (*Gr. Rhodon, rose*)		45	3	102.91	Wollaston (E)	1803
Rubidium (Rb) (*Rubidus, red*)	2	37	1	85.44	Bunsen, Kirchoff (G)	1861
Ruthenium (Ru) (*Ruthenia, Russia*)	7	44	3–4–6–8	101.7	Klaus (Ru)	1844
Samarium (Sm) (*Samarski, a Russian*)		62	3	150.43	Boisbaudran (F)	1879
Scandium (Sc) (*Scandinavia*)	1	21	3	45.10	Nilson (S)	1879
Selenium (Se) (*Gr. selene, moon*)	6	34	2–4–6	78.96	Berzelius (S)	1818
Silicon (Si) (*Silex, flint*)	3	14	4	28.06	Berzelius (S)	1823
Silver (Ag) (*Argentum*)	2	47	1	107.880	Ancient	B.C.
Sodium (Na) (*Natrium*)	1	11	1	22.997	Davy (E)	1807
Strontium (Sr) (*Strontian, in Scotland*)	3	38	2	87.63	Crawford, 1790, Davy (E)	1808
Sulfur (S)	3	16	2–4–6	32.06	Ancient	B.C.
Super-Uranium		93			Fermi (I)	1934
Tantalum (Ta)		73	5	181.4	Ekeberg (S)	1802
Tellurium (Te) (*Tellus, earth*)	4	52	2–4–6	127.61	Reichenstein (Au)	1782
Terbium (Tb) (*Ytterby, in Sweden*)		65	3	159.2	Mosander (S)	1843
Thallium (Tl) (*Thallus, budding twig*)	3	81	1–3	204.39	Crookes (E)	1861
Thorium (Th) (*God, Thor*)	8	90	4	232.12	Berzelius (S)	1828
Thulium (Tm) (*Thule, Northland*)		69	3	169.4	Cleve (S)	1879
Tin (Sn) (*Stannum*)	11	50	2–4	118.70	Ancient	B.C.
Titanium (Ti) (*Titanes, sons of earth*)	1	22	3–4	47.90	Gregor (E)	1791
Tungsten (W) (*Wolframium, heavy stone*)	4	74	6	184.0	d'Elhuyar Brothers (Sp)	1783
Uranium (U) (*Planet Uranus*)	8	92	4–6	238.14	Klaproth (G)	1789
Vanadium (V) (*Goddess, Vanadis*)	1	23	3–5	50.95	Sefstrom (S)	1830
Virginium		87	1		Allison, Murphy (A)	1930
Xenon (Xe) (*Gr. Xenos, strange*)	9	65	0–8	131.3	Ramsay, Travers (E)	1898
Ytterbium (Yb) (*Ytterby, in Sweden*)	1	70	3	173.04	Marignac (F)	1878
Yttrium (Y) (*Ytterby, in Sweden*)	1	39	3	88.92	Gadolin (Fi)	1794
Zinc (Zn)	5	30	2	65.38	Marggraf (G)	1746
Zirconium (Zr)	5	40	4	91.22	Klaproth (G)	1789

(A) American; (Au) Austrian; (C) Canadian; (H) Dutch; (Da) Danish; (E) English; (F) French; (Fi) Finnish; (G) German; (H) Hungarian; (I) Italian; (R) Roman; (Ru) Russian; (S) Swedish; (Sp) Spanish

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DETROIT, MICHIGAN

A.I.S.I. Standard Steel Compositions

Revised Feb. 1, 1943

Openhearth Alloy and Electric Furnace Carbon and Alloy Steels

(Blooms, Billets, Slabs, Bars and Hot Rolled Strip)

AISI Number	C	Mn	P Max.*	S Max.*	Si*	Ni	Cr	Mo	'42 SAE Number
A 1330	0.28–0.33	1.60–1.90	0.040	0.040	0.20–0.35	.....	.....	.....	1330
A 1335	0.33–0.38	1.60–1.90	0.040	0.040	0.20–0.35	.....	.....	.....	1335
A 1340	0.38–0.43	1.60–1.90	0.040	0.040	0.20–0.35	.....	.....	.....	1340
A 1345	0.43–0.48	1.60–1.90	0.040	0.040	0.20–0.35	.....	.....	.....	....
A 1350	0.48–0.53	1.60–1.90	0.040	0.040	0.20–0.35	.....	.....	.....	....
A 2317	0.15–0.20	0.40–0.60	0.040	0.040	0.20–0.35	3.25–3.75	.....	.....	2315 2317
A 2330	0.28–0.33	0.60–0.80	0.040	0.040	0.20–0.35	3.25–3.75	.....	.....	2330
A 2335	0.33–0.38	0.60–0.80	0.040	0.040	0.20–0.35	3.25–3.75	.....	.....	....
A 2340	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	3.25–3.75	.....	.....	2340
A 2345	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	3.25–3.75	.....	.....	2345
E 2512	0.09–0.14	0.45–0.60	0.025	0.025	0.20–0.35	4.75–5.25	.....	.....	....
A 2515	0.12–0.17	0.40–0.60	0.040	0.040	0.20–0.35	4.75–5.25	.....	.....	2515
E 2517	0.15–0.20	0.45–0.60	0.025	0.025	0.20–0.35	4.75–5.25	.....	.....	....
A 3115	0.13–0.18	0.40–0.60	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	.....	3115
A 3120	0.17–0.22	0.60–0.80	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	.....	3120
A 3130	0.28–0.33	0.60–0.80	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	.....	3130
A 3135	0.33–0.38	0.60–0.80	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	.....	3135
A 3140	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	.....	3140
A 3141	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	1.10–1.40	0.70–0.90	.....	X3140 3141
A 3145	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	1.10–1.40	0.70–0.90	.....	3145
A 3150	0.48–0.53	0.70–0.90	0.040	0.040	0.20–0.35	1.10–1.40	0.70–0.90	.....	3150
A 3240	0.38–0.45	0.40–0.60	0.040	0.040	0.20–0.35	1.65–2.00	0.90–1.20	.....	3240
E 3310	0.08–0.13	0.45–0.60	0.025	0.025	0.20–0.35	3.25–3.75	1.40–1.75	.....	3310 3312
E 3312	0.14–0.19	0.45–0.60	0.025	0.025	0.20–0.35	3.25–3.75	1.40–1.75	.....	....
A 4023	0.20–0.25	0.70–0.90	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30	4023
A 4024	0.20–0.25	0.70–0.90	0.040	(a)	0.20–0.35	.....	.....	0.20–0.30	....
A 4027	0.25–0.30	0.70–0.90	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30	4027
A 4028	0.25–0.30	0.70–0.90	0.040	(a)	0.20–0.35	.....	.....	0.20–0.30	....
A 4032	0.30–0.35	0.70–0.90	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30	4032
A 4037	0.35–0.40	0.75–1.00	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30	4037
A 4042	0.40–0.45	0.75–1.00	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30	4042
A 4047	0.45–0.50	0.75–1.00	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30	4047
A 4063	0.60–0.67	0.75–1.00	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30	4063
A 4068	0.64–0.72	0.75–1.00	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30	4068
A 4119	0.17–0.22	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.40–0.60	0.20–0.30	4119
A 4120	0.17–0.22	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.60–0.80	0.20–0.30	....
A 4125	0.23–0.28	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.40–0.60	0.20–0.30	4125
A 4130	0.28–0.33	0.40–0.60	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25	X4130 4130
A 4131	0.28–0.33	0.50–0.70	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.14–0.19	....
E 4132	0.30–0.35	0.40–0.60	0.025	0.025	0.20–0.35	.....	0.80–1.10	0.18–0.25	....
A 4134	0.32–0.37	0.40–0.60	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25	....
E 4135	0.33–0.38	0.70–0.90	0.025	0.025	0.20–0.35	.....	0.80–1.10	0.18–0.25	....
A 4137	0.35–0.40	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25	4137
E 4137	0.35–0.40	0.70–0.90	0.025	0.025	0.20–0.35	.....	0.80–1.10	0.18–0.25	....
A 4140	0.38–0.43	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25	4140
A 4141	0.38–0.43	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.14–0.19	....
A 4142	0.40–0.45	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25	....
A 4143	0.40–0.45	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.20–0.30	....
A 4145	0.43–0.48	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25	4145
A 4147	0.45–0.52	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25	....
A 4150	0.46–0.53	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25	4150
E 4150	0.48–0.53	0.70–0.90	0.025	0.025	0.20–0.35	.....	0.80–1.10	0.20–0.27	....
A 4317	0.15–0.20	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	0.40–0.60	0.20–0.30	....
A 4320	0.17–0.22	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	0.40–0.60	0.20–0.30	4320
A 4337	0.35–0.40	0.60–0.80	0.040	0.040	0.20–0.35	1.65–2.00	0.60–0.80	0.30–0.40	....
E 4337	0.35–0.40	0.60–0.80	0.025	0.025	0.20–0.35	1.65–2.00	0.70–0.90	0.23–0.30	....
A 4340	0.38–0.43	0.60–0.80	0.040	0.040	0.20–0.35	1.65–2.00	0.70–0.90	0.20–0.30	X4340 4340
E 4342	0.40–0.45	0.60–0.80	0.025	0.025	0.20–0.35	1.65–2.00	0.70–0.90	0.23–0.30	....
A 4608	0.06–0.11	0.40 max.	0.040	0.040	0.25 max	1.40–1.75	.....	0.15–0.25	....
A 4615	0.13–0.18	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	.....	0.20–0.30	4615
E 4617	0.15–0.20	0.45–0.65	0.025	0.025	0.20–0.35	1.65–2.00	.....	0.20–0.27	....
A 4620	0.17–0.22	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	.....	0.20–0.30	4620
E 4620	0.17–0.22	0.45–0.65	0.025	0.025	0.20–0.35	1.65–2.00	.....	0.20–0.27	....
A 4621	0.18–0.23	0.70–0.90	0.040	0.040	0.20–0.35	1.65–2.00	.....	0.20–0.30	....
A 4640	0.38–0.43	0.60–0.80	0.040	0.040	0.20–0.35	1.65–2.00	.....	0.20–0.30	4640
E 4640	0.38–0.43	0.60–0.80	0.025	0.025	0.20–0.35	1.65–2.00	.....	0.20–0.27	....
A 4645	0.43–0.48	0.60–0.80	0.040	0.040	0.20–0.35	1.65–2.00	.....	0.20–0.30	....
A 4815	0.13–0.18	0.40–0.60	0.040	0.040	0.20–0.35	3.25–3.75	.....	0.20–0.30	4815
A 4820	0.18–0.23	0.50–0.70	0.040	0.040	0.20–0.35	3.25–3.75	.....	0.20–0.30	4820
A 5120	0.17–0.22	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.70–0.90	.....	5120
A 5130	0.28–0.33	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.80–1.10	.....	....
A 5140	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.70–0.90	.....	5140
A 5145	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.70–0.90	.....	....
A 5150	0.48–0.55	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.70–0.90	.....	5150
A 5152	0.45–0.55	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.90–1.20	.....	....
E 52995	0.95–1.10	0.25–0.45	0.025	0.025	0.20–0.35	.....	0.40–0.60	.....	....
E 52998	0.95–1.10	0.25–0.45	0.025	0.025	0.20–0.35	.....	0.90–1.15	.....	....
E 52100	0.95–1.10	0.25–0.45	0.025	0.025	0.20–0.35	.....	1.20–1.50	.....	....
E 52101	0.95–1.10	0.25–0.45	0.025	0.025	0.20–0.35	.....	1.30–1.60	.....	....
A 6120	0.17–0.22	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.70–0.90	0.10 min.V	....
A 6145	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15 min.V	....
BAE 6150	0.48–0.55	0.65–0.90	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15 min.V	6150
E 6151	0.47–0.53	0.70–0.90	0.025	0.025	0.20–0.35	.....	0.80–1.10	0.15 min.V	....
A 6152	0.48–0.55	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.10 min.V	....
A 9255	0.50–0.60	0.70–0.95	0.040	0.040	1.80–2.20	.....	.....	.....	....
A 9260	0.55–0.65	0.75–1.00	0.040	0.040	1.80–2.20	.....	.....	.....	....
A 9262	0.55–0.65	0.75–1.00	0.040	0.040	1.80–2.20	.....	0.20–0.40	.....	....

*Lowest standard maximum phosphorus or sulphur content for acid openhearth or acid electric furnace alloy steel is 0.05% each; silicon is 0.15% min.

NOTE (a)—Sulphur range: 0.035 to 0.050%.

CODE FOR PREFIXES:

A is basic openhearth alloy steel.
B is acid bessemer carbon steel.
C is basic openhearth carbon steel.
D is acid openhearth carbon steel.
E is electric furnace steel.
NE is National Emergency standard steel; designation promulgated by W.P.B.
Q is forging quality, or special requirement quality.
R is re-rolling quality billets.

Basic Openhearth and Acid Bessemer Carbon Steels

AISI Number	Semi-finish	Bars	Wire Rods	C	Mn	P (b)	S (b)	'42 SAE Number
C 1005	—	—	√	0.06 max.	0.35 max.	0.04	0.05	....
C 1006*	Q, R	√	√	0.08 max.	0.25–0.40	0.04	0.05	....
C 1008*	Q, R	√	√	0.10 max.	0.30–0.50	0.04	0.05	1008
CB 1008	—	√	√	0.10 max.	.....	....	....	....
C 1009	Q	—	—	0.07–0.13	0.25–0.40	0.04	0.05	....
C 1010*	Q, R	√	√	0.08–0.13	0.30–0.50	0.04	0.05	1010
C 1012	Q	√	√	0.10–0.15	0.30–0.50	0.04	0.05	....
CB 1012	—	√	—	0.15 max.	.....	....	....	....
C 1013	—	√	√	0.11–0.16	0.60–0.90	0.04	0.05	....
C 1014	Q	√	√	0.13–0.18	0.40–0.60	0.04	0.05	....
C 1015*	Q, R	√	√	0.13–0.18	0.30–0.50	0.04	0.05	1015
C 1016	Q	√	√	0.13–0.18	0.60–0.90	0.04	0.05	X1015 1016
CB 1017	—	√	—	0.10–0.25	.....	....	....	....
C 1017	—	√	√	0.15–0.20	0.40–0.60	0.04	0.05	....
C 1018	Q	√	√	0.15–0.20	0.60–0.90	0.04	0.05	....
C 1019	Q	√	√	0.15–0.20	0.70–1.00	0.04	0.05	....
C 1020*	Q, R	√	√	0.18–0.23	0.30–0.50	0.04	0.05	1020
C 1021	Q	√	√	0.18–0.23	0.60–0.90	0.04	0.05	....
C 1022	Q	√	√	0.18–0.23	0.70–1.00	0.04	0.05	X1030 1022
C 1023	Q	√	√	0.20–0.25	0.30–0.50	0.04	0.05	....
C 1024	—	—	√	0.20–0.26	1.35–1.65	0.04	0.05	1024
C 1025*	Q, R	√	√	0.22–0.28	0.30–0.50	0.04	0.05	1025
C 1026	Q	√	√	0.22–0.28	0.40–0.60	0.04	0.05	....
C 1027	—	√	√	0.24–0.30	0.40–0.60	0.04	0.05	....
C 1029	Q	√	√	0.25–0.31	0.60–0.90	0.04	0.05	....
C 1030	Q	√	√	0.28–0.34	0.60–0.90	0.04	0.05	1030
C 1031	Q	—	—	0.28–0.34	0.40–0.60	0.04	0.05	....
CB 1032	R	√	—	0.25–0.40	.....	....	....	....
C 1033	Q	√	—	0.30–0.36	0.60–0.90	0.04	0.05	....
C 1034	—	—	√	0.32–0.38	0.50–0.70	0.04	0.05	....
D 1034	—	—	√	0.32–0.38	0.50–0.70	0.05	0.05	....
C 1035	Q	√	—	0.32–0.38	0.60–0.90	0.04	0.05	1035
C 1036	—	√	—	0.32–0.39	1.20–1.50	0.04	0.05	1036
C 1037	C.r. strip	—	—	0.32–0.38	0.40–0.60	0.04	0.05	....
C 1038	Q	—	√	0.35–0.42	0.60–0.90	0.04	0.05	....
C 1039	C.r. strip	—	—	0.37–0.44	0.40–0.60	0.04	0.05	....
C 1040	Q	√	√	0.37–0.44	0.60–0.90	0.04	0.05	1040
C 1041	—	—	√	0.36–0.44	1.35–1.65	0.04	0.05	....
C 1042	Q	√	—	0.40–0.47	0.60–0.90	0.04	0.05	....
C 1043	Q	√	—	0.40–0.47	0.70–1.00	0.04	0.05	....
C 1044	—	√	—	0.43–0.50	0.50–0.70	0.04	0.05	....
C 1045	Q	√	—	0.43–0.50	0.60–0.90	0.04	0.05	1045
C 1046	Q	—	—	0.43–0.50	0.70–1.00	0.04	0.05	....
C 1047	C.r. strip	—	—	0.43–0.50	0.40–0.60	0.04	0.05	....
C 1049	C.r. strip	—	—	0.48–0.55	0.40–0.60	0.04	0.05	....
D 1049	—	√	√	0.43–0.50	0.50–0.70	0.05	0.05	....
C 1050	Q	√	—	0.48–0.55	0.60–0.90	0.04	0.05	1050
C 1051	—	√	√	0.45–0.56	0.85–1.15	0.04	0.05	....
C 1052	—	√	—	0.47–0.55	1.20–1.50	0.04	0.05	1052
C 1054	—	—	√	0.50–0.60	0.50–0.70	0.04	0.05	....
D 1054	—	—	√	0.50–0.60	0.50–0.70	0.05	0.05	....
C 1055	Q	—	—	0.50–0.60	0.60–0.90	0.04	0.05	1055
C 1056	C.r. strip	—	—	0.50–0.60	0.40–0.60	0.04	0.05	....
C 1057	—	—	√	0.50–0.61	0.85–1.15	0.04	0.05	....
C 1058	C.r. strip	—	—	0.55–0.65	0.40–0.60	0.04	0.05	....
C 1059	—	—	√	0.55–0.65	0.50–0.70	0.04	0.05	....
D 1059	—	—	√	0.55–0.65	0.50–0.70	0.05	0.05	....
C 1060	—	√	√	0.55–0.65	0.60–0.90	0.04	0.05	1060
C 1061	—	√	—	0.54–0.65	0.75–1.05	0.04	0.05	....
C 1062	—	—	√	0.54–0.65	0.85–1.15	0.04	0.05	....
C 1063	—	—	√	0.57–0.67	0.60–0.85	0.04	0.05	....
C 1064	—	√	√	0.60–0.70	0.50–0.70	0.04	0.05	....
D 1064	—	—	√	0.60–0.70	0.50–0.70	0.05	0.05	....
C 1065	Strip	—	—	0.60–0.70	0.60–0.90	0.04	0.05	....
C 1066	—	√	√	0.60–0.71	0.80–1.10	0.04	0.05	X1065 1066
C 1068	—	√	—	0.65–0.75	0.50 max.	0.04	0.05	....
C 1069	—	√	√	0.65–0.75	0.50–0.70	0.04	0.05	....
D 1069	—	—	√	0.65–0.75	0.40–0.60	0.05	0.05	....
C 1070	—	√	—	0.65–0.75	0.70–1.00	0.04	0.05	1070
C 1074	—	√	√	0.70–0.80	0.50–0.70	0.04	0.05	....
D 1074	—	—	√	0.70–0.80	0.40–0.60	0.05	0.05	....
C 1075	—	—	√	0.70–0.80	0.60–0.80	0.04	0.05	....
C 1076	Q	—	—	0.65–0.85	0.60–0.85	0.04	0.05	....
C 1078	—	√	√	0.72–0.85	0.30–0.50	0.04	0.05	....
D 1078	—	—	√	0.70–0.85	0.30–0.50	0.05	0.05	....
C 1080	—	√	—	0.75–0.88	0.60–0.90	0.04	0.05	1080
D 1083	—	—	√	0.80–0.95	0.30–0.50	0.05	0.05	....
C 1084	Q	—	—	0.80–0.93	0.60–0.90	0.04	0.05	....
C 1085	Q	—	—	0.80–0.91	0.70–1.10	0.04	0.05	1085
C 1086	Q	√	√	0.83–0.95	0.30–0.50	0.04	0.05	....
C 1090	Q	—	—	0.85–1.00	0.60–0.90	0.04	0.05	....
C 1095	—	√	√	0.90–1.05	0.30–0.50	0.04	0.05	1095
D 1095	—	—	√	0.90–1.05	0.30–0.50	0.05	0.05	....
B 1006	—	—	√	0.08 max.	0.45 max.	0.11 max.	0.06 max.	....
B 1008	R	√	—	0.10 max.	0.30–0.50	0.11 max.	0.06 max.	....
B 1011	—	√	√	0.13 max.	0.50–0.70	0.11 max.	0.06 max.	....

*Compositions are given for forging quality; re-rolling quality differs slightly in analysis.

Note 1: When silicon is specified in standard basic openhearth steels, silicon may be ordered only as 0.10 per cent maximum; 0.10 to 0.20 per cent; or 0.15 to 0.30 per cent. In the case of many grades of basic openhearth steel, special practice is necessary in order to comply with a specification including silicon.

Note 2: Acid bessemer steel is not furnished with specified silicon content.

Sulphurized or Phosphorized Carbon Steels

AISI Number	Semi-finish	Bars	Wire Rods	C	Mn	P (b)	S (b)	'42 SAE Number
B 1106	—	—	√	0.09 max.	0.50 max.	0.11 max.	0.04–0.09	....
C 1108	—	—	√	0.08–0.13	0.50–0.70	0.045 max.	0.07–0.12	....
C 1109	Q	√	√	0.08–0.13	0.60–0.90	0.045 max.	0.08–0.13	....
B 1110	—	√	√	0.13 max.	0.60 max.	0.11 max.	0.045–0.075	....
C 1110	—	√	√	0.08–0.13	0.60–0.90	0.045 max.	0.10–0.15	....
B 1111	—	√	√	0.08–0.13	0.60–0.90	0.08–0.13	0.10–0.15	1111
C 1111	—	—	√	0.08–0.13	0.60–0.90	0.045 max.	0.10–0.23	....
B 1113	—	√	√	0.08–0.13	0.60–0.90	0.08–0.13	0.16–0.23	1113
C 1113	—	√	—	0.10–0.16	1.00–1.30	0.045 max.	0.08–0.13	....
B 1113	—	√	√	0.08–0.13	0.60–0.90	0.08–0.13	0.24–0.33	X1112 1113
C 1113	Q	√	—	0.10–0.16	1.00–1.30	0.045 max.	0.24–0.33	....
C 1114	R	—	—	0.12–0.18	0.45–0.65	0.045 max.	0.075–0.15	....
C 1115	Q	√	√	0.13–0.18	0.70–1.00	0.045 max.	0.10–0.15	1115
C 1116	Q	√	√	0.14–0.20	1.10–1.40	0.045 max.	0.16–0.23	....
C 1117	—	√	√	0.14–0.20	1.00–1.30	0.045 max.	0.08–0.13	X1314 1117
C 1118	Q	√	√	0.14–0.20	1.30–1.60	0.045 max.	0.08–0.13	X1315 1118
C 1119	—	—	√	0.14–0.20	1.35–1.65	0.045 max.	0.16–0.23	....
C 1120*	Q, R	√	√	0.18–0.23	0.60–0.90	0.045 max.	0.08–0.13	....
C 1131	Q	√	√	0.18–0.23	0.70–1.00	0.045 max.	0.08–0.13	....
C 1132	Q	√	√	0.17–0.23	1.35–1.65	0.045 max.	0.08–0.13	....
C 1133	Q	√	√	0.27–0.34	1.35–1.65	0.045 max.	0.08–0.13	X1330 1133
C 1137	Q	√	√	0.33–0.39	1.35–1.65	0.045 max.	0.08–0.13	X1335 1137
C 1140‡	Q	—	—	0.37–0.44	0.60–0.90	0.045 max.	0.04–0.07	....
C 1141	—	√	—	0.37–0.45	1.35–1.65	0.045 max.	0.08–0.13	X1340 1141
C 1144	—	√	—	0.40–0.48	1.35–1.65	0.045 max.	0.24–0.33	....
C 1145‡	Q	—	—	0.42–0.49	0.70–1.00	0.045 max.	0.04–0.07	1145
C 1205	Q	—	√	0.06 max.	0.25–0.40	0.04–0.07	0.05 max.	....
C 1206	R	—	√	0.08 max.	0.25–0.40	0.06–0.10	0.05 max.	....
C 1209	R	—	√	0.08–0.13	0.30–0.50	0.04–0.07	0.05 max.	....
C 1210	Q	—	√	0.08–0.13	0.30–0.50	0.06–0.10	0.05 max.	....
C 1217	—	√	—	0.14–0.19	0.70–1.00	0.09–0.13	0.20–0.28	....

*Compositions given are for forging quality; re-rolling quality differs slightly in analysis.

(b)—Phosphorus and sulphur are maximum for basic openhearth and acid bessemer steels; sulphurized or phosphorized steels are not subject to check analysis for S or P.

Notes: Acid bessemer steels (B series) are not furnished with specified silicon content.

‡Standard steels C 1140 and C 1145 may be ordered with silicon content either as 0.10% max., 0.10 to 0.30%, or 0.15 to 0.30%.

Working On The Squeezer Machine

This molder is making a small steel casting on the "squeezer" machine. He is contented not alone because he is a skilled craftsman with a profession, but because steel foundries do provide modern facilities for the efficient production of sorely-needed castings.

You know there is an urgent need for help in making small castings. The manpower shortage in the steel foundries is severe, and the call is out for skilled and unskilled workers—now.

But, in the meantime, such men as this skilled molder are carrying through the production of the steel castings you need in your war-essential equipment. From the careful melting of the proper alloys,to the final cleaning and finishing operations on the steel castings themselves, your steel foundries are delivering quality and service.

Remember the advantages of steel casting design in your own plans for war or postwar equipment. One of the steel foundries listed on these pages will be happy to show you how steel castings will do the job more efficiently and more economically.

create steel castings

Chicago
Burnside Steel Foundry Company
1300 East 92nd St. SAGinaw 9600

Los Angeles, Calif.
Utility Electric Steel Foundry
3334 East Slauson Ave. Kimball 4185

Tulsa, Oklahoma
Oklahoma Steel Castings Company
1200 N. Peoria. 5-9286

Toledo, Ohio
Unitcast Corporation, Steel Casting Div.
Front and Millard Ave. POntiac 1545

Detroit, Michigan
Detroit Steel Casting Company
4069-4140 Mich. Ave., LAfayette 5710

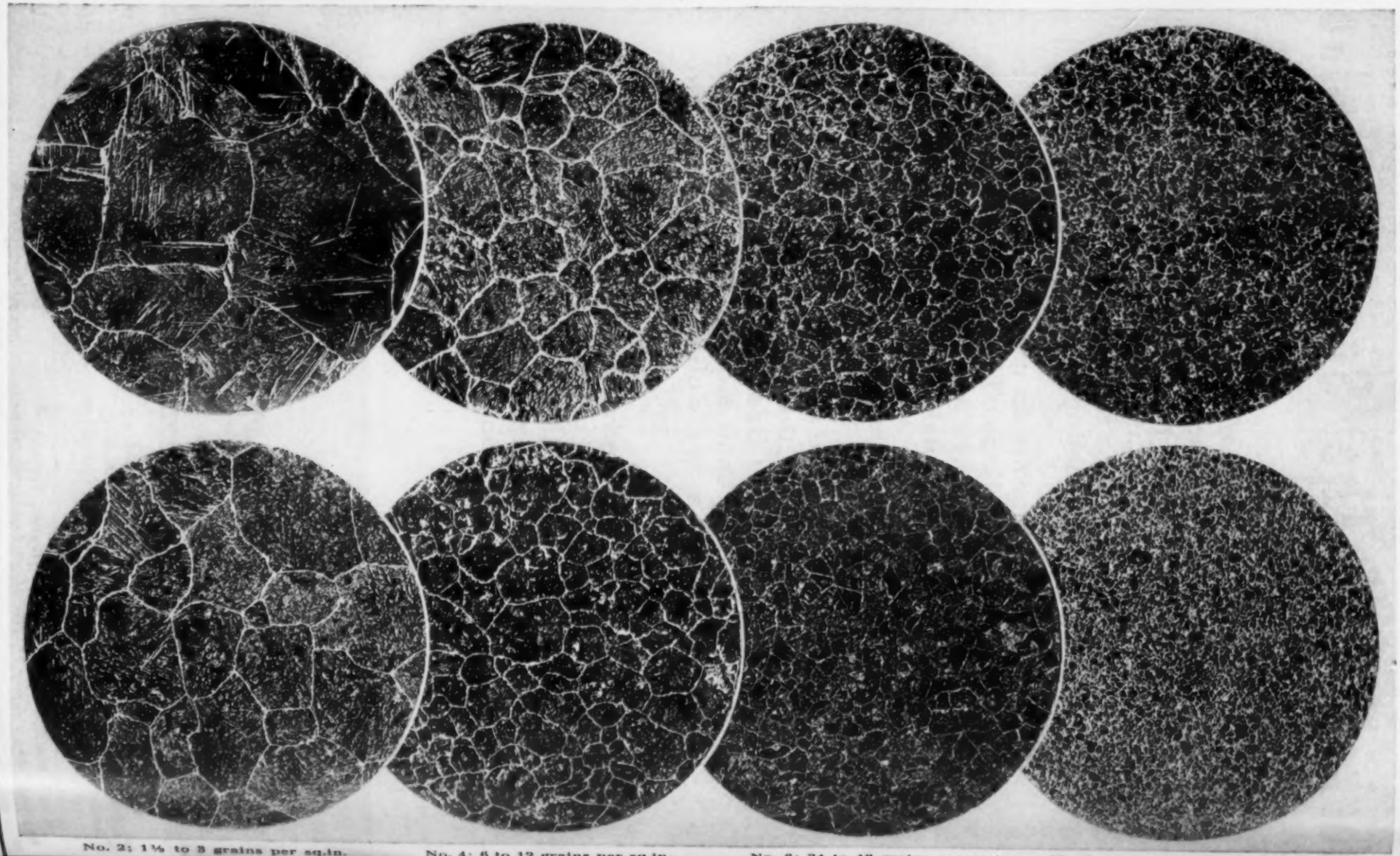
Houston, Texas
Texas Electric Steel Casting Company
Bringhurst & Gillespie. Fairfax 8117

Buffalo, N. Y.
Strong Steel Foundry Co.
51 Norris St. Riverside 2700

Standard Grain Sizes for Steels

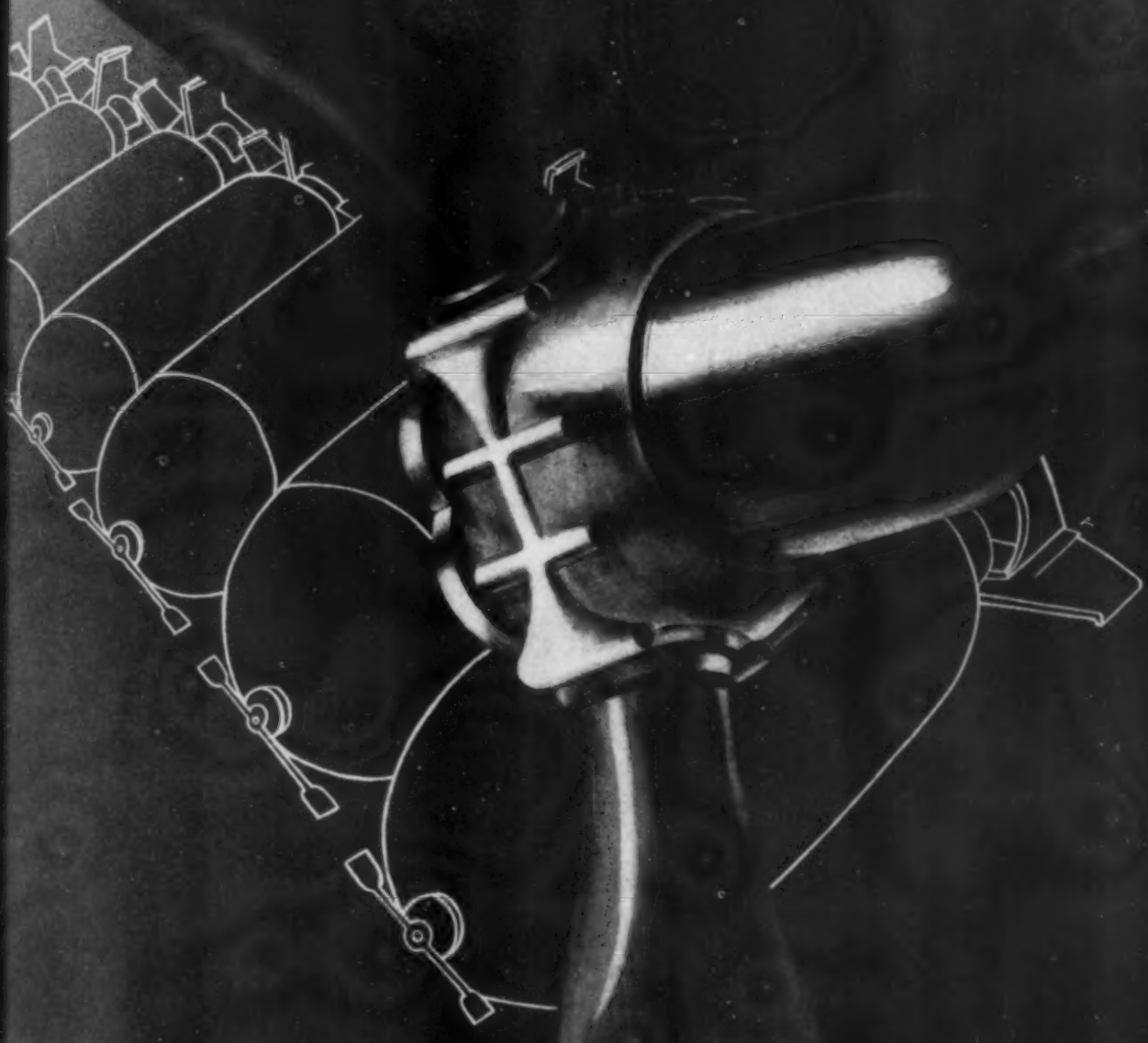
Carburized and slowly cooled to develop cementite network. Magnified 100 diameters. Micros courtesy Timken Roller Bearing Co.

Grain Size No. 1; Up to 1½ per sq.in. No. 3; 3 to 6 grains per sq.in. No. 5; 12 to 24 grains per sq.in. No. 7; 48 to 96 grains per sq.in.



No. 2; 1½ to 3 grains per sq.in. No. 4; 6 to 12 grains per sq.in. No. 6; 24 to 48 grains per sq.in. No. 8; More than 96 grains per sq.in.

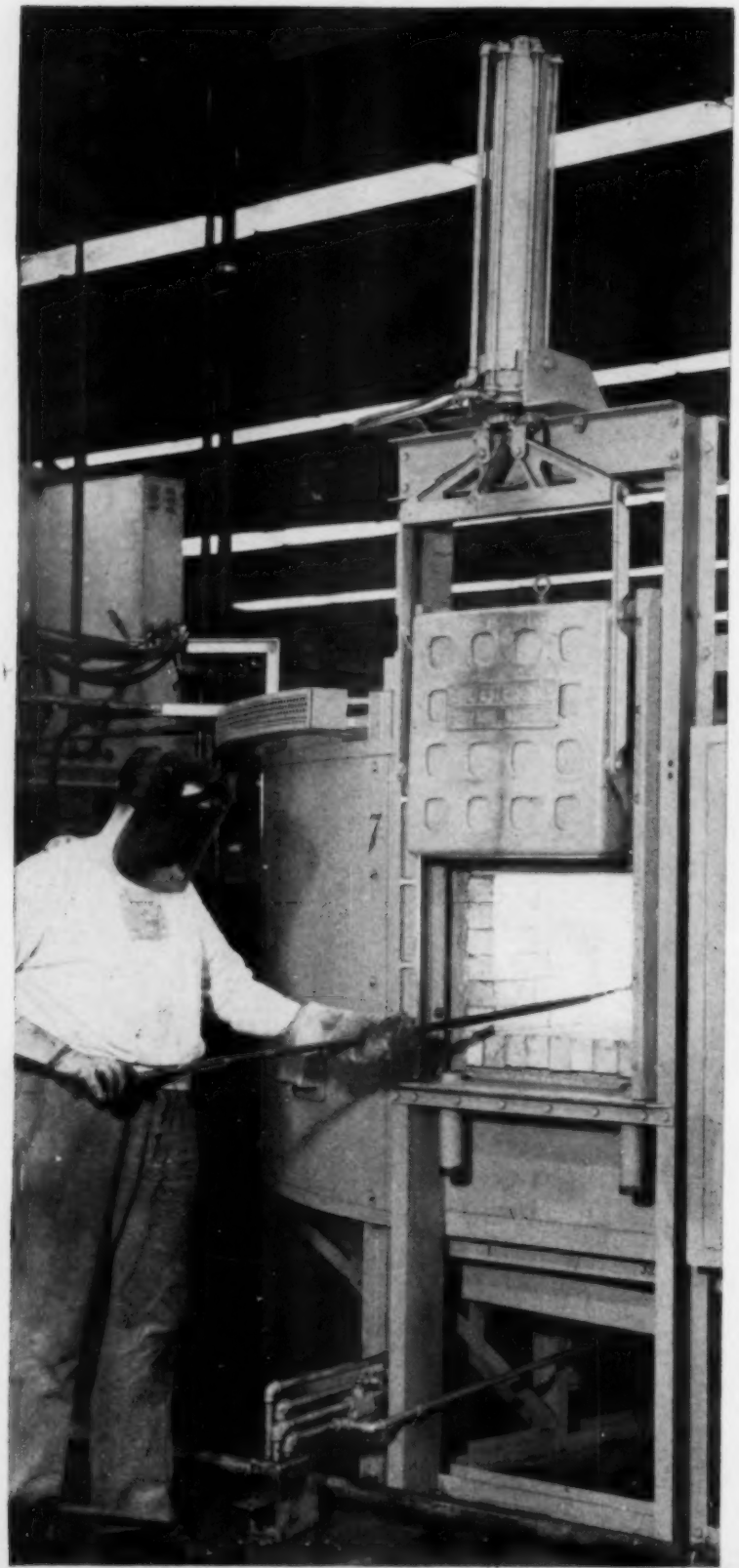
non-ferrous metals



annual reference issue

october 1944

No. 2; 1½ to 3 grains per sq.in. No. 4; 6 to 12 grains per sq.in. No. 6; 24 to 48 grains per sq.in. No. 8; More than 96 grains per sq.in.



Some of the things you should know about

"GLOBAR" POWERED

ELECTRIC FORGING FURNACES

Metals and alloys of all types are uniformly heated—clean and scale free. Under proper conditions of furnace chamber atmosphere, steels are heated without decarburization and the grain structure of the metal retains its desired characteristics.

"Globar" powered electric forging furnaces bring to you these five benefits:

1. Improved quality of forging.

2. Refractories in electric forges last years instead of weeks.

3. Makes possible a clean, well-lighted forge shop.

4. Increased production per furnace and per man.

5. Elimination of rejections due to burning—carbon spots—improper filling of die due to uneven heating.

There are other benefits we would like to tell you about—write and tell us when we can discuss them with you. The Carborundum Company, Globar Division, Niagara Falls, New York.

This 125 KW rotary hearth "Globar" equipped furnace is one of eight such furnaces which were manufactured by Sylvester and Company, Cleveland, Ohio and have been in service over two years. Continuous conveyor and batch type forging furnaces by Sylvester have also established production records in the war effort.

"Globar" Heating Elements by CARBORUNDUM

TRADE MARK

(Carborundum and Globar are registered trade marks of and indicate manufacture by The Carborundum Company)

The Modern Bearings

● The latest liquid-cooled and the latest air-cooled aircraft engines, the various U.S. Army trucks, two famous British artillery pieces—all have one thing in common. They contain more sleeve bearings than bearings of all other types combined.

The war has stimulated advances in sleeve bearing design and manufacture, making the sleeve bearing successful where other types have failed.

The Bunting organization has contributed its share to this advance. Bunting Cast Bronze Bearings are manufactured in stock or special dimensions, to standard or precision tolerances. Write for catalog.

Factory Finished Tubular and Solid Bars of Bearing Bronze are available for your own manufacture of special bearings. Ask your wholesaler... The Bunting Brass & Bronze Company, Toledo 9, Ohio... Warehouses in Principal Cities. 3

Bunting

BRONZE BUSHINGS ☆ BEARINGS ☆ PRECISION BRONZE BARS

Identification of Constituents in Commercial Aluminum Alloys

By F. Keller and G. W. Wilcox, Aluminum Research Laboratories (After Dix and Keith, with additions)

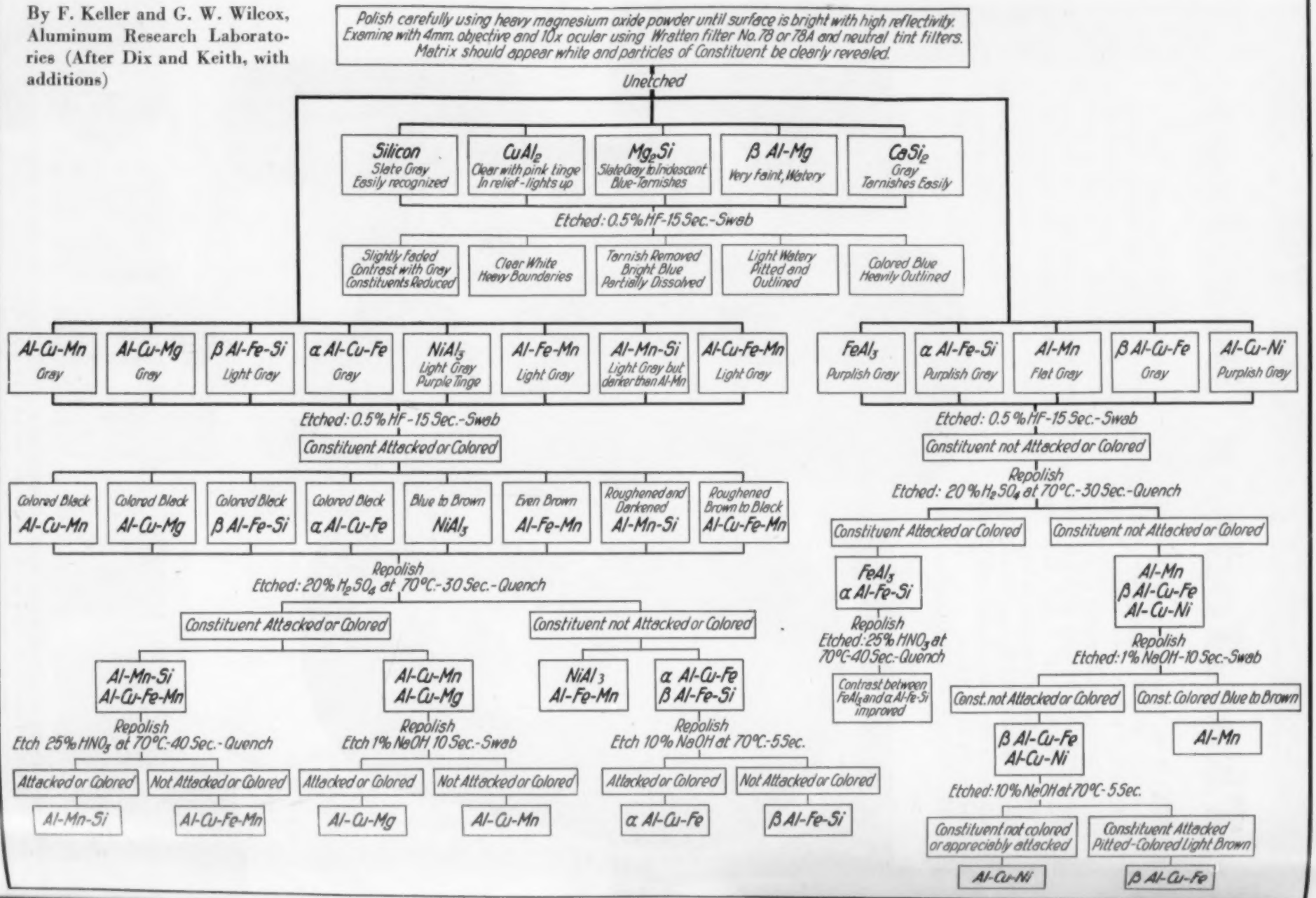


Photo Courtesy National Smelting Co., Cleveland, Ohio

ELIMINATE OXIDE INCLUSIONS
FROM ALL YOUR ALUMINUM ALLOY PRODUCTS

●

Originally devised for aluminum rolling mills and continuous casting, the Ajax-Tama-Wyatt induction melting furnace has been adopted for the widest possible range of uses today.

Small, compact twin-coil foundry units are now available! Plants using these furnaces have invariably developed vastly increased physicals in rolling mill, die cast, or aluminum foundry products . . . with decreased gas absorption, absence of all segregation, and elimination of oxide inclusions and hard spots. *That is a significant statement, well worth investigation.*

Contrary to traditional thinking, metal from this furnace may be cast directly into molds without necessity of a "holding" furnace of any sort.

Clean-cut temperature control, great ease and simplicity of handling are operating characteristics. The furnace gives you a cooler foundry and a better product. *Write for the TW group of bulletins.*

Remember, Ajax-Tama-Wyatt units are the only induction furnaces ever built with the precise nature and metallurgical properties of aluminum specifically in mind. *Arrange to visit our plant to run your own experimental heats where desirable!*

See us at the Metal Show, Cleveland, this year
AJAX ENGINEERING CORP., TRENTON 7, N. J.

A Compact Low Cost Induction Furnace is on Display Ajax Booth C-330 !

THE **AJAX** TAMA-WYATT **INDUCTION MELTING FURNACE**

ASSOCIATE COMPANIES
AJAX METAL COMPANY, Non-Ferrous Ingot Metals and Alloys for Foundry Use
AJAX ELECTROTHERMIC CORP., Ajax-Northrup High Frequency Induction Furnaces
AJAX ELECTRIC CO., INC , The Ajax-Hultgren Electric Salt Bath Furnace
AJAX ELECTRIC FURNACE CORP., Ajax-Wyatt Induction Furnaces for Melting

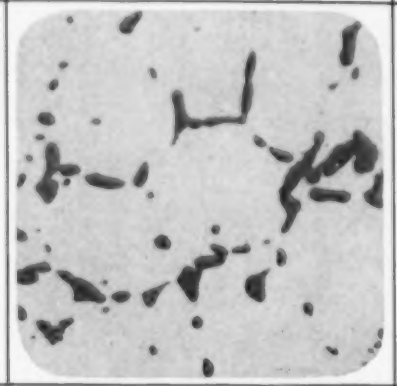
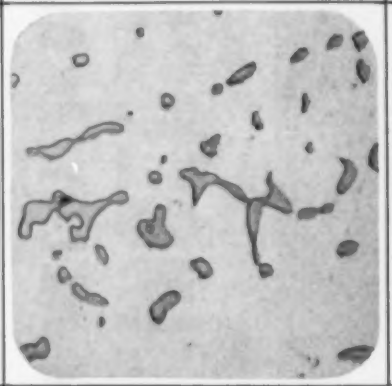
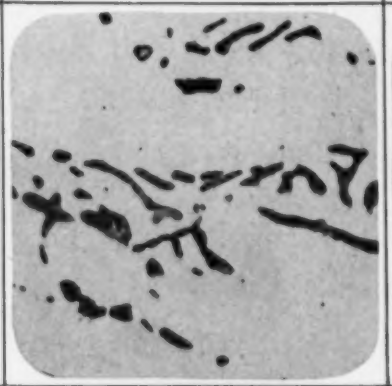
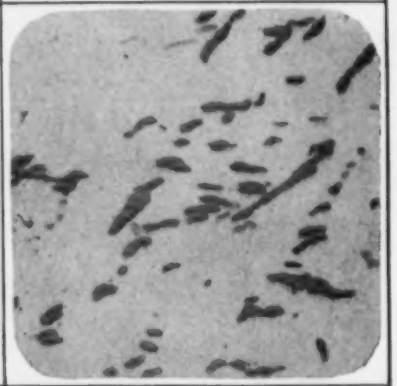
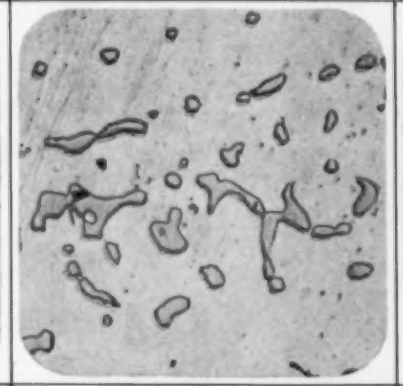
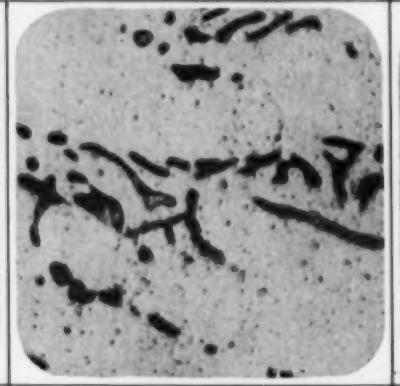
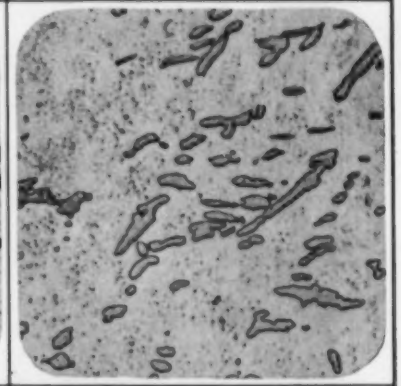
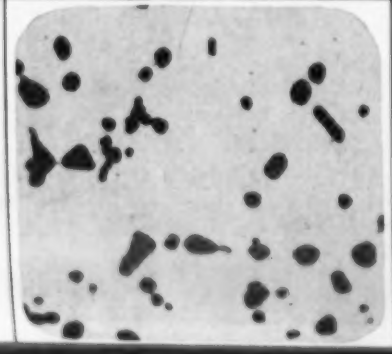
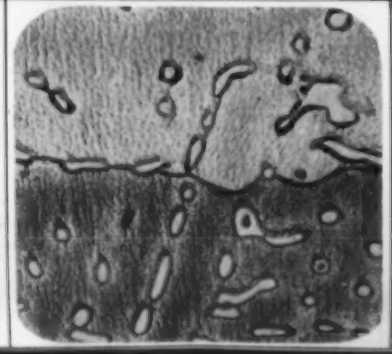
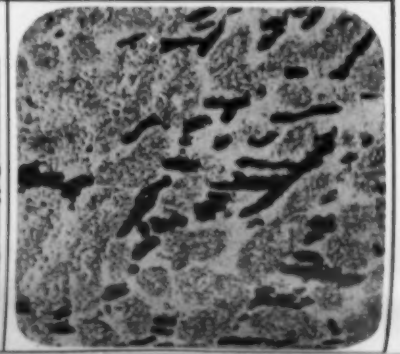
Learn Why Other Plants Have Developed Vastly Increased Physicals in Aluminum Products!

4.4 % Cu
1.5 % Mg
0.6 % Mn
Bal Al
Incidental Si and Fe

CONSTITUENTS OF 24S ALLOY

ETCHING CHARACTERISTICS

By F. Keller
and R.A. Bossert
Aluminum Research Laboratories

ETCHING TREATMENT	CONSTITUENT, (As It Appears in Synthetic Alloy of Extreme Purity)			
	Al-Cu-Mg	$CuAl_2$	Mg_2Si	Al-Cu-Fe-Mn
No etch; Photographed as polished				
$NaOH$-Na_2CO_3-$(Zn.Sn)Cl_2$ solution for 5 min. Cleaned with conc. HNO_3				
HF-HCl-HNO_3 solution for 15 sec.				

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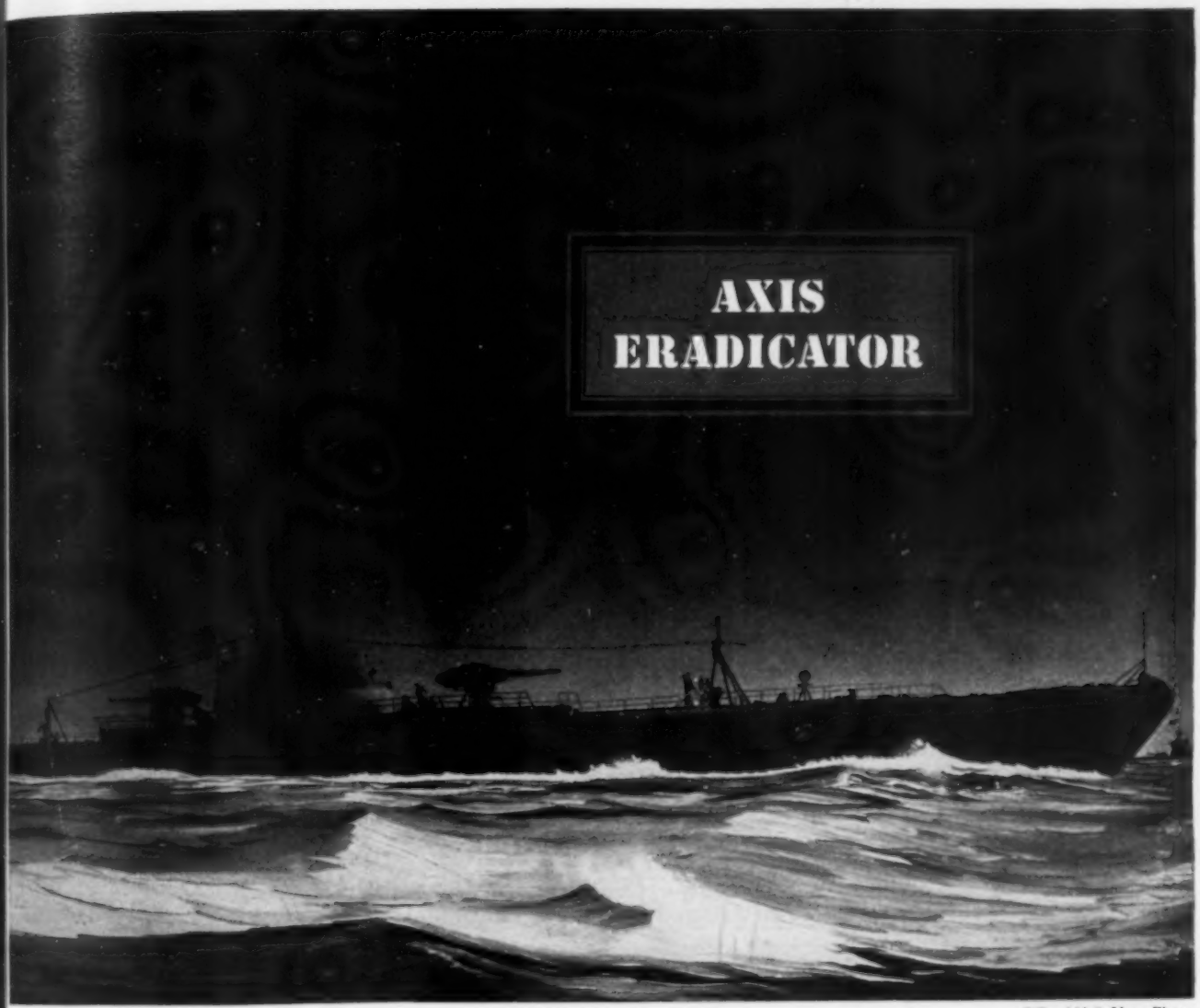

Official U.S. Navy Photo

FEDERATED Brass and Bronze Alloys

are used in ever increasing amounts by the builders of these and other "axis eradicators".

From periscope to torpedo, the submarine is a precision built instrument of destruction. It is essential that its constituent metals be above reproach in quality and uniformity.

Federated brass and bronze alloys are of uniform high quality due to advanced technical knowledge and precision control of metallurgical processes.

Federated Metals will meet your requirements and save you money. Your inquiry will receive prompt attention from the Federated Office nearest you.

INGOT METALS AND WHITE METAL ALLOYS PRODUCED BY FEDERATED

ALUMINUM
BRASS
BRONZE
DIE CAST ALLOYS
SOLDER
BABBITT
TYPE METAL
ZINC DUST

All of these in standard specifications. Special alloys to your order.

FMD

Federated

METALS DIVISION

AMERICAN SMELTING and REFINING COMPANY

120 BROADWAY, NEW YORK (5) N. Y.

Nation-wide service with offices in principal cities

Etching Characteristics of Constituents in Aluminum Alloys

By Research Laboratory, Aluminum Co. of America

Constituents	Reagent					
	0.5% HF Swab for 15 seconds, wash in cold water	1% NaOH Swab for 10 seconds, wash in running water	20% H_2SO_4 at 70°C., immerse specimen for 30 seconds, quench in cold water	25% HNO_3 at 70°C., immerse specimen for 40 seconds, quench in cold water	10% NaOH at 70°C., immerse specimen for 5 seconds, rinse in cold water	0.5% HF, 1.5% HCl, 2.5% HNO_3, immerse specimen for 15 sec., rinse in warm water
Silicon	Outlined. Unattacked. Color lightened.	Outlined. Unattacked. Color slightly lightened.	Unattacked. Color lightened.	Outlined. Unattacked. Color lightened.	Outlined. Unattacked. Color lightened.	Outlined. Unattacked. Color lightened.
Mg_2Si	Colored bright blue.	Outlined. Color unchanged.	Action violent. Some particles dissolved, any left have a blue color.	Colored brown or black.	Outlined. Color lightened.	Outlined. Colored blue to brown.
$CuAl_2$	Outlined. Part of pinkish tinge removed. Constituent light and clear.	Outlined. Part of pinkish tinge removed. Constituent light and clear.	Outlined. Part of pinkish tinge removed. Constituent light and clear.	Colored brown or black.	Pitted. Colored light to dark brown.	Outlined. Constituent light and clear.
β Al-Mg	Outlined. Slightly clearer and more watery. Black pits appear in particles.	Not Outlined. Unattacked. Uncolored.	Attacked vigorously resulting in pitting. Some particles dissolved.	Heavy attack, particles grayish and watery.	Outlined. Unattacked. Uncolored.	Heavily outlined. Attacked by pitting.
$FeAl_3$	Slightly darkened. Brown stains appear on large primary particles.	Outlined. Slightly darkened.	Heavily attacked. Particles often dissolved or deeply pitted. Color darkened.	Outlined. Contrast with Al-Fe-Si improved.	Outlined. Colored deep brown.	Outlined. Uncolored. Slightly attacked.
α Al-Fe-Si	Outlined. Not colored.	Outlined. Not colored.	Outlined. Blackened and attacked.	Outlined. Contrast with $FeAl_3$ improved.	Attacked. Blackened.	Heavily outlined. Darkened and roughened.
β Al-Fe-Si	Blackened and attacked	Outlined. Uncolored. Unattacked.	Outlined. Slightly darkened and pitted.	Outlined. Uncolored. Unattacked.	Outlined. Slightly darkened and attacked.	Outlined. Slightly darkened and roughened.
Al-Mn	Outlined. Slightly darkened.	Attacked. Colored brownish or bluish but coloring is uneven.	Outlined. Uncolored. Unattacked.	Not Outlined. Unattacked. Uncolored.	Colored blue or brown.	Outlined. Unattacked. Uncolored.
$NiAl_3$	Outlined. Colored blue and brown.	Outlined. Darkened slightly. Not colored.	Outlined. Darkened slightly. Not colored.	Outlined. Uncolored. Unattacked.	Colored blue to deep brown.	Colored brown to black.
Al-Fe-Mn	Outlined. Colored brown. (Sometimes bluish)	Outlined. Particles pitted. (Often a rough blue color on a few particles.)	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Colored deep brown to blue.	Outlined. Attacked. Darkened.
Al-Cu-Ni	Outlined. Unattacked. Darkened.	Outlined. Slightly darkened. Not attacked.	Outlined. Slightly darkened. Not attacked.	Blackened. Some particles dissolved.	Outlined. Unattacked. Uncolored.	Outlined. Some large particles stained unevenly.
α Al-Cu-Fe	Outlined. Blackened.	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Outlined. Blackened. Attacked.	Blackened.
β Al-Cu-Fe	Outlined. Unattacked. Uncolored.	Outlined. Slightly darkened.	Outlined and uncolored. Often show black cores which are probably $FeAl_3$	Outlined. Slightly darkened. Unattacked.	Pitted. Colored light brown.	Outlined. Blackened.
Al-Cu-Fe-Mn	Outlined. Colored light brown to black. Usually appears roughened.	Outlined. Uncolored.	Outlined. Blackened.	Outlined. Unattacked. Uncolored.	Outlined. Uncolored.	Outlined. Colored brown to black.
Al-Mn-Si	Outlined. Colored light brown to black. Usually appears roughened.	Outlined. Usually appears rough and attacked. Slightly darkened.	Outlined. Appears rough and attacked. Darkened slightly.	Outlined. Appears rough. Darkened slightly.	Outlined. Attacked. Color not changed.	Outlined. Slightly darkened.
Al-Cu-Mg	Outlined. Blackened.	Outlined. Colored light brown.	Outlined. Attacked. Blackened.	Outlined. Attacked. Blackened.	Outlined. Unattacked. Colored brown.	Colored brown to black.
$CaSi_2$	Colored blue. Heavily outlined.	Outlined. Color unchanged.	Outlined. Colored blue. Roughened.	Outlined. Unattacked. Uncolored.	Outlined. Blackened. Attacked and roughened.	Colored brown to blue. Mottled.
Al-Cu-Mn	Outlined. Attacked. Blackened.	Outlined. Unattacked. Uncolored.	Outlined. Colored light brown.	Outlined. Unattacked. Uncolored.	Outlined. Attacked. Blackened.	Attacked. Blackened.
$CrAl_7$	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Outlined. Colored blue to brown unevenly.	Outlined. Unattacked. Uncolored.
Al-Cr-Fe	Colored light brown. Unattacked.	Not outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Not outlined. Unattacked. Uncolored	Small particles colored brown to black. Large particles stained all colors.	Outlined. Colored light brown. Not attacked.

IN THIS REYNOLDS PLANT airplane engine baffles by the million are turned out from sheet aluminum rolled in other Reynolds plants.

REYNOLDS ALUMINUM:

To cool America's sky horses—Aluminum takes strange shapes

LOOK, for a minute, inside the huge, blocks-long Plant No. 14 of Reynolds Aluminum . . .

Before you spreads out a strange and fascinating sight . . . sheets of shining aluminum are being stamped by batteries of huge machines into queer, exciting shapes ...some that remind you of unusual-looking pudding molds . . . other shapes that look like tomorrow's kitchen utensils.

These strange shapes of aluminum are known to airplane technicians as *baffles*—and they are vitally essential to every air-cooled warplane engine. Fitted around the engine's cylinders, they are carefully designed to catch the flow of air . . . to circulate it evenly around every cylinder.

It was in answer to an SOS call from the engine-makers that Reynolds Aluminum went into production of baffles. "We've hit a bottle-neck," said the manufacturers. "You people have broken other bottle-necks in the industry—can you turn out baffles for us?"

Just to set up a plant of the size needed was a monumental job. It meant precision sheet metal work to extremely close tolerances. Stamping machines had to be assembled from the four corners of the country; heat-treating equipment had to be built; a special conveyor system designed. But five months after that SOS was received, the Reynolds plant was put into operation. Already the number of baffles turned out for America's warplane engines runs into the millions.

A PROMISE FOR TOMORROW

After the war, the giant machines in this huge plant can quickly be turned to producing better, more efficient pots and pans than American women have ever known. But for the present, Reynolds Aluminum is concentrating on "the future that counts most"—that time between today and the day of complete victory for our forces.

REYNOLDS METALS CO.
Aluminum and Parts Div., Louisville 1, Ky.

REYNOLDS ALUMINUM BAFFLES fitted around the cylinders of the powerful Pratt & Whitney engine on these Grumman F6F Hellcat planes catch the air that keeps the engine cool, efficiently operating.

THE MIRACLE of Reynolds Aluminum is portrayed in unforgettable fashion in the new sound movie, "A Recital of Faith." It shows how Reynolds scrapped all precedent and created a huge new source of aluminum, to speed Victory and provide an abundance of low-cost alloys for post-war uses. For a private showing to interested executives in your organization, write Reynolds Metals Co.

Copper and Its Alloys in Wrought Form

Prepared by M. G. Steele, Technical Adviser, Revere Copper and Brass, Inc.

Metal	Type Composition					Properties (Hard & Soft)			Forms	Properties and Uses	Methods of Working
	Cu	Zn	Pb	Sn	Ni	Tensile Strength	Elong-ation	Elastic Limit			
Copper (electrolytic)	99.9					51,000 32,500	4 47	48,000 12,000	Sheet; Bar; Tube; Rod; Plate	Corrosion resistance; ductility; high conductivity. Roofing; bus bar; high conductivity tubing	Stamp; Draw Weld; Solder; Forge; Form
Copper (lake)	99.9	7 oz. silver per ton				51,000 32,000	4 47	48,000 12,000	Sheet; Strip; Rod	High annealing point. Auto radiator fins; lock seam tubing	Stamp; Draw Solder; Form
Copper (phosphorized)	99.9	0.04 phosphorus max.				55,000 35,000	5 45	44,000 16,000	Sheet; Strip; Tube	Draws and coils better than electrolytic. Water, refrigerator and oil-burner tubing	Stamp; Draw Forge
Copper (arsenical)	99.9	0.04 phosphorus 0.30 arsenic				60,000 36,000	4 40	55,000 7,000	Sheet; Tube; Plate	High strength; resists heat and flaking. Condenser tubes	Stamp; Draw; Forge
Copper (cadmium)	99	1.00 cadmium				80,000 35,000	4 45	68,000	Rod	High strength. High strength parts; trolley wire	Draw; Forge
Copper (beryllium)	98	2.00 beryllium				175,000 75,000	6 45	134,000 31,000	Sheet; Tube; Rod	Very high strength; hardness; high conductivity. Springs; cutting tools	Stamp; Draw Forge; Form
Brasses											
Gilding metal	95	5				55,000 35,000	5 38	39,000 11,000	Sheet; Strip; Tube	Ductility; reddish gold color. Primers; detonator fuse caps; jewelry; forgings	Stamp; Draw Forge; Form
Commercial bronze	90	10				67,000 37,000	3 40	53,000 11,000	Sheet; Strip; Tube	Ductility. Used for color match; stamped hardware; bullet jackets; jewelry; caskets; screen cloth	Stamp; Draw Forge; Form; Perforate
Rich low brass	85	15				75,000 42,000	4 43	52,000 15,000	Sheet; Strip; Tube	Corrosion resistance. Brass pipe; jewelry; badges; name plates; etchings; tags; dials	Stamp; Form Draw; Blank; Etch; Weld
Low brass	80	20				85,000 43,000	4 50	65,000 15,000	Sheet; Strip; Tube	Corrosion resistance; yellow color. Jewelry (for gold plating); fulton bellows.	Stamp; Form Draw; Spin
Seventy-thirty or cartridge brass	70	30				86,000 45,000	4 50	65,000 15,000	Sheet; Strip Tube	High ductility; deep drawing. Pins; rivets; eyelets; radiators; cartridge shells; spun articles	Stamp; Spin; Deep Drawing
High brass	66	34				90,000 48,000	4 50	70,000 15,000	Sheet; Strip	High ductility; deep drawing. Brass pipe; auto reflectors; stampings; radiator fins	Stamp; Spin; Deep Drawing
Leaded high brass	65	33.5	1.5			80,000 45,000	5 60	60,000 15,000	Sheet; Strip	Forming by bending; free machining. Engravers' brass; lighting fixtures; clock and watch backs; gears; keys	Stamp; Form Bend; Punch
Free cutting rod	62	35	3			62,000 47,000	20 60	25,000 15,000	Rod	Typical brass rod; free machining. Extruded shapes; screw machine parts	Machine; Thread; Extrude
Forging rod	60	38	2			70,000 50,000	10 45	31,000 15,000	Rod	Hot forgings; faucet handles; shower heads	Forge; Extrude Machine;
Muntz metal	60	40				80,000 57,000	9.5 48	60,000 15,000	Sheet; Plate; Tubes	Condenser tubes and heads; ship sheathing; perforated metal; brazing rod	Draw; Punch Forge
Architectural bronze	56	41.25	2.75			70,000 50,000	10 20	55,000 15,000	Sheet; Strip	Strength; hardness; free cutting. Extruded shapes; forgings; interior ornamental bronze	Extrude; Forge; Machine
Special Brasses											
Silicon brass	78	20	2.0 silicon			110,000 55,000	4 61	83,000 12,500	Sheet; Strip	High strength; weldability. Refrigerator evaporators; fire extinguisher shells	Resistance Weld; Stamp; Draw
Aluminum brass	76	22	2.0 aluminum			83,000 62,000	17 52	75,000 16,000	Tube	Resistance to corrosion and erosion; self healing skin. Condenser tubes	Draw; Extrude
Admiralty	71	28		1		95,000 45,000	5 60	92,000 18,000	Sheet; Strip; Tube	Resistance to corrosion, especially of sea water. Condenser tubes	Stamp; Draw; Extrude
Naval brass	60	39.25		0.75		75,000 54,000	15 45	39,000 15,000	Sheet; Rod; Tube	Resistance to corrosion in sea water. Tube heads; marine shafting; bolts; forged parts; window anchors	Draw; Forge
Bronzes											
Phosphor bronze	98.75	0.05 phosphorus		1.2		65,000 40,000	4 48	50,000 15,000	Sheet; Strip	Resilience; strength; hardness; corrosion resistance. Springs; bearings; small parts	Stamp; Form; Weld
Phosphor bronze	92	0.05 phosphorus		8		110,000 55,000	3 55	85,000 25,000	Sheet; Strip; Rod	Similar to above. Welding rod	Stamp; Form; Weld
Silicon bronze	96.25	3.25 silicon		0.50		110,000 60,000	5 55	100,000 25,000	Sheet; Tube; Rod	Strength; weldability; corrosion resistance. Tanks; bolts; screws; lags; chain; locomotive hub liners; welding rod.	Stamp; Draw Forge; Weld; Extrude; Cast
Aluminum bronze	95	5.0 aluminum				105,000 57,000	5 55	80,000 24,000	Sheet; Tube; Rod	Corrosion resistance; strength; golden color. Condenser tubes; gift articles	Stamp; Extrude; Draw
Manganese bronze	59	39	1.25 Fe.	0.75	0.05 Mn	75,000 60,000	5 35	50,000 15,000	Sheet; Strip; Rod	Resistance to wear and corrosion. Welding rod; perforated coal screens; extruded wearing parts	Extrude; Perforate; Weld
Nickel-Silvers											
Nickel silver (typical)	65	20			15	93,000 58,000	5.5 45	75,000 15,000	Sheet; Strip; Rod	Resistance to corrosion; strength. Extruded shapes; table silver; instruments; key stock; springs	Forge; Extrude; Stamp
Cupro-Nickels											
Cupro-nickel eighty-twenty)	80				20	80,000 49,000	3 42	78,000 17,000	Tube	Resistance to corrosion, erosion, heat and chemical attack. Condenser tubes	
Cupro-nickel seventy-thirty)	70				30	84,000 49,000	4 50	83,000 18,300	Tube	Same as above but more resistant to corrosion. Condenser tubes	
Cupro-nickel (zinc alloy)	75	5			20	85,000 50,000	5 35	77,000 23,000	Sheet; Tube; Rod	Same as 80-20 above but less resistant to corrosion. Condenser tubes	

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Magnesium Alloys

Compositions, Properties, and Designations of American Commercial Alloys

Compiled by H. S. Jerabek, University of Minnesota, W. H. Gross of The Dow Chemical Co., and R. T. Wood of American Magnesium Corp.

Form	A.S.T.M. Alloy No.	A.S.T.M. Specification No.	Navy Bureau of Aeronautics Alloy No.	Navy Bureau of Aeronautics Specification No.	Navy Department Alloy No.	Navy Department Specification No.	U.S. Army Air Forces Grade	U.S. Army Air Forces Specification No.	S.A.E. No.	AMS(j)	Am. Mg. Corp. AM No.	Dow Chem. Co.	Composition, Per Cent Magnesium-Remainder Al	Mn	Zn	Condition	Tensile Strength (a) Typical	Tensile Strength (a) Min.	Yield Strength (a) Typical	Yield Strength (a) Min.	Elongation in 2 In., % Typical	Elongation in 2 In., % Min.	Brinell Hardness	Shear Strength (a)	Endurance (b)	Uses and Characteristics
Sand Castings	4	B80-41T	A	AN-QQ-M-56	A	AN-QQ-M-56	A	AN-QQ-M-56	50	4420A	265-C	H	6.0	0.2	3.0	As Cast	27	24	11	10	5	4	51	17	10	General casting use
							A			4422A	265-T4					Cast; Soln. T. (c)	37	30	12	10	10	7	53	18	10	Sand & permanent mold castings
							A			4424A	265-T6					Cast; Soln. T.; Aged (d)	37	32	18	16	4	3	70	19	9	
	12	B80-41T	C	AN-QQ-M-56	C	AN-QQ-M-56	C	AN-QQ-M-56	500		260-C	C	9.0	0.1	2.0	As Cast	23	20	14	10	1		62	18	10	Pressure tight castings
											260-T4					Cast; Soln. T. (c)	39	32	14	10	10	6	61	20	10	Sand & permanent mold castings
										4434	260-T6					Cast; Soln. T.; Aged (d)	38	34	20	18	3	1	77	22	10	
	2	B80-41T									240-C	G	10.0	0.1		As Cast	21	18	12	10	2	1	53	18	8	Sand & permanent mold castings
											240-T4					Cast; Soln. T.; (c)	33	29	12	10	8	5	52	20	10	
											240-T6					Cast; Soln. T.; Aged (d)	34	29	19	17	1		69	22	8	
	3	B80-41T									248-T6	B	12.0	0.1		-"- -"- -"-	32	27	20	17	0.5		85	19	7	Hard castings. Pistons
	11	B80-41T	B	AN-QQ-M-56	B	AN-QQ-M-56	B	AN-QQ-M-56			403-C	M		1.5		As Cast	14	12	4		5	3	33	11		Best salt water resistance
											244-C		4.0	0.3		-"- -"-	24	20	9	8	6	4	44	14		Aircraft tank fittings
Die Castings	12	B94-41T				46M11	1	11319			230-C	K	10.0	0.1	(f)	As Cast	30		22		1		68			Thin section die castings
	13	B94-41T				46M11	1	11319	501	4490	263-C	R	9.0	0.2	0.6	-"- -"-	33		20		3		66			General die castings
Extruded Bars and Rods	8	B107-41T	8	M-314C(e)			1	11335(e)		4350A	57S	J	6.5	0.2	0.7	-"- -"- (g)	43	40	30	26	17	12	54		17	Improved strength
	8	B107-41T	8	M-314C(e)			1	11335(e)	520		57S	J	6.5	0.2	0.7	-"- -"- ; Stretched	44	40	32	26	15	12	55	20	15	Screw machine rod
	11	B107-41T	11	M-314C			2	11336			3S	M		1.5		-"- -"-	42	32	27	20	6	3	42		10	Best salt water resistance
	9	B107-41T									58S	O	8.5	0.2	0.5	-"- -"-	47	43	33	28	11	9	61		17	Bars of high strength
	15	B107-41T	15	M-314C(e)			1	11337(e)	521		C74S	X	3.0	0.2	3.0	-"- -"-	42	39	30	26	19	15	51		18	Heat treatable bar
	15a	B107-41T	15a	M-314C(e)			1	11337(e)	521		C74S-T5	X				-"- -"- ; Aged	44	41	34	30	13	10	54		17	
											59S	G	10.0	0.1		-"- -"- ; Stretched	51	45	38	33	9	6	70	23	16	Highest hardness & strength
	18	B107-41T									52S	Fs	2.8	0.3	1.0	-"- -"- -"-	40	37	30	25	17	12	50	19	12	Good ductility & impact toughness
Extruded Structural Shapes	8	B107-41T	8	M-314C(e)			1	11335(e)	520	4350A	57S	J	6.5	0.2	0.7	As Extruded	42	38	27	23	15	10	58			Good strength & weldability
	11	B107-41T	11	M-314C			2	11336			3S	M		1.5		-"- -"-	35	30	23	16	6	3	42			Best salt water resistance
	15	B107-41T	15	M-314C(e)			1	11337(e)	521		C74S-T5	X	3.0	0.2	3.0	-"- -"-	42	39	25	22	17	10	59			Heat treatable shapes
	15a	B107-41T	15a	M-314C(e)			1	11337(e)	521		C74S	X				-"- -"- ; Aged	43	40	28	25	14	8	62			
	9	B107-41T									58S	O	8.5	0.2	0.7	As Extruded	44	40	29	25	11	8	58			Improved strength
											59S	G	10.0	0.1		-"- -"-	48	45	37	30	9	6				Highest hardness & strength
	18	B107-41T					1	11320(e)			52S	Fs	2.8	0.3	1.0	-"- -"-	39	34	28	17	15	10				Good ductility & impact toughness
Extruded Tubing					8	44T35(e)	1	11332(e)	520		57S	J	6.5	0.2	0.7	As Extruded	40	36	19	17	9	7	55			Good strength & weldability
					11	44T35	2	11333			3S	M		1.5		-"- -"-	35	32	17	17	5	3	40			Best salt water resistance
					15	44T35(e)	1	11334(e)	521		C74S	X	3.0	0.2	3.0	-"- -"-	40	36	19	17	9	7	55			Heat treatable tubing
									521		C74S	X				-"- -"- ; Aged	41	37	22	19	7	6	59			
											C58S-T5	O	8.5	0.2	0.7	-"- -"- -"-	42	39	29	25	5	4	60			Highest strength tubing
							1	11318(e)			52S	Fs	2.8	0.3	1.0	As Extruded	35	32	16		11		50			Good ductility
Press Forgings	8	B91-41T			8	46M13(e)		11345		4350A	C57S	J	6.5	0.2	0.7	As Forged	41	38	25	22	9	6	56	21	17	General forging. Good ductility
					11	46M13						M		1.5		-"- -"-	33	29	19	12	6	2	43			Weldable forgings
	9	B91-41T			9	46M13(e)		11321A(e)		4360	C58S	O	8.5	0.2	0.5	-"- -"-	45	42	30	24	7	5	69	22	18	Forgings, simple design. Strong
	15	B91-41T			15	46M13(e)					C74S	X	3.0	0.2	3.0	-"- -"-	41	38	24	20	16	9	59		17	Heat treatable forgings
	15a	B91-41T			15a	46M13(e)					C74S-T5	X				-"- -"- ; Aged	42	38	28	22	14	7	62		17	
Hammer Forgings	16	B91-41T			16	46M13		11346			65S		3.5	0.2	(h)	As Hammer Forged	38	35	22	20	12	6	52	16	10.5	Hammer forgings
												L	3.0	0.2	(i)	-"- -"- -"-	37	34	26	19	11	6	51		10.5	-"- -"-
Rolled Plate, Sheet & Strip	11	B90-41T			11	47M2	1	11339	51	4370	3S-H	Mh		1.5		As Hard Rolled	37	32	27	24	9	4	53			Sheet with best formability & salt water resistance
									51	4370	3S-O	Ma				Annealed	32	28	16		15	12	44	17	8	
	8	B90-41T			8	47M2(e)	2	11338(e)		4381	C52S-H	J-1h	6.5	0.2	0.7	As Hard Rolled	45	40	35	28	8	3		20		Sheet with best combination of strength & salt water resistance
										4380	C52S-O	J-1a				Annealed	40	37	25		15	8		21		
	18	B90-41T			18	47M2(e)		11340(e)			C52S-H	Fs-1h	2.7	0.3	1.0	As Hard Rolled	45	38	35	26	9	4				General purpose sheet alloy
											C52S-O	Fs-1a				Annealed	36	32	22		18	12				Good formability & strength

(a) In 1000 psi. Yield strength is the stress at which the stress-strain curve deviates 0.2 % from the modulus line.

(b) Endurance or fatigue limit for 500 million reversals of the load, in 1000 psi.

(c) Solution heat treatment: Soaking at about 680 to 810 °F. followed by air quenching.

(d) Solution treatment followed by artificial aging at about 350 °F. (precipitation hardening).

(e) Compositions with 0.005 % Fe max. and 0.006 % Ni max., for improved resistance to salt water are required by these specifications (Dowmetal J-1, O-1, X-1; AMC 57S, AM-C58S, AM-C74S, AM-C52S).

(f) Contains 0.5 % silicon.

(g) Extruded and stretched is the condition in which bar and rod is normally furnished.

(h) Contains 5.0 % tin.

(i) Contains 3.5 % cadmium.

(j) Aeronautical material specification, Society of Automotive Engineers, Inc.

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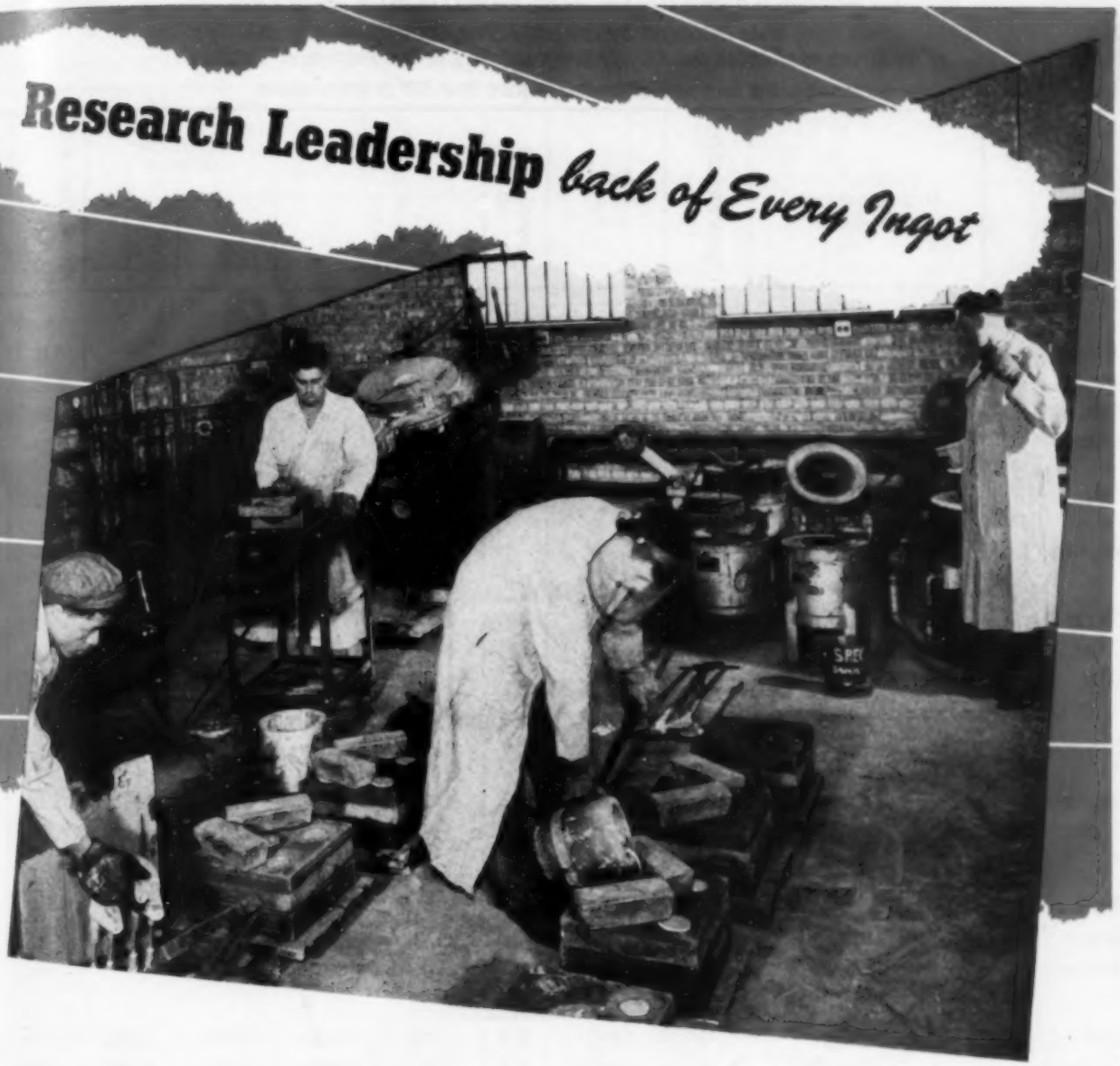

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Crystallography of the Chemical Elements

As Tabulated by William Hume-Rothery

in "The Structure of Metals and Alloys," Monograph No. 1, British Institute of Metals.

Emendations (by H.C. Vacher) represent values that have appeared in the literature from 1936 to 1940 inclusive.

Element Atomic No.	Electron Arrangement in Free Atoms	Crystal Structure (Note a)	Axial Ratio c÷a	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter Coordination No. 12 (Note f)	Reference (g)
Group I A in Periodic Sequence										
3, Lithium	[2] 1	⧉	—	8	3.5019±2	—	3.033	—	3.13	13
11, Sodium	[2][8] 1	⧉	—	8	4.2820±5	—	3.708	—	3.82	10
19, Potassium	[2][8][8] 1	⧉	—	8	5.333 5	—	4.618	—	4.76	—
37, Rubidium	[2][8][18][8] 1	⧉	—	8	5.62±0.03 at -173°C.	—	4.87 at -173°C.	—	5.02	—
55, Cesium	[2][8][18][18][8] 1	⧉	—	8	6.05±0.03 at -173°C.	—	5.24 at -173°C.	—	5.40	—
87, Virginium	[2][8][18][32][18][8] 1	—	—	—	—	—	—	—	—	—
Group I B										
29, Copper	[2][8][18] 1	⊡	—	12	3.6078	—	2.5511	—	2.551	—
47, Silver	[2][8][18][18] 1	⊡	—	12	4.0778	—	2.8835	—	2.883	—
79, Gold	[2][8][18][32][18] 1	⊡	—	12	4.0690	—	2.8778	—	2.877	—
Group II A in Periodic Sequence										
4, Beryllium	[2] 2	α=○	1.5848	6,6	2.2679	3.5942	2.2235	2.2679	2.25	—
		β=○	1.52	—	?.1	10.8	—	—	—	1
12, Magnesium	[2][8] 2	○	1.6236	6,6	3.2022	5.1991	3.1900	3.2022	3.20	—
20, Calcium	[2][8][8] 2	α=⊡	—	12	5.56	—	3.93	—	3.93	—
at 300°C.		β=?	—	—	—	—	—	—	—	1
at 460°C.		γ=○	1.64	6,6	3.94	6.46	3.94	3.955	3.98	—
38, Strontium	[2][8][18][8] 2	⊡	—	12	6.075	—	4.296	—	4.296	—
56, Barium	[2][8][18][18][8] 2	⧉	—	8	5.015	—	4.343	—	4.48	—
88, Radium	[2][8][18][32][18][8] 2	—	—	—	—	—	—	—	—	—
Group II B										
30, Zinc	[2][8][18] 2	○	1.8560	6,6	2.6590	4.9351	2.6590	2.9061	2.748	—
48, Cadmium	[2][8][18][18] 2	○	1.8859	6,6	2.9731±2	5.6069±5	2.9731	3.2872	3.042	1
80, Mercury	[2][8][18][32][18] 2	▱	α=70°31.7'	6	2.999 at -46°C.	—	2.999	—	3.10	—
Group III A in Periodic Sequence										
5, Boron	[2] 3	○	—	—	—	—	—	—	—	1
13, Aluminum	[2][8] 3	⊡	—	12	4.0414±2	—	2.8577	—	2.80 to 2.86 (note b)	
21, Scandium	[2][8][9] 2	α=⊡	—	12	4.532	—	3.925	—	3.925	12
		β=○	1.585	6,6	3.30	5.23	3.23	3.30	3.265	12
39, Yttrium	[2][8][18][9] 2	○	1.588	6,6	3.663	5.814	3.595	3.663	3.629	—
57, Lanthanum	[2][8][18][18][9] 2	α=○	1.613	6,6	3.754	6.063	3.727	3.754	3.741	—
		β=⊡	—	12	5.296	—	3.745	—	3.745	—
89, Actinium	[2][8][18][32][18][9] 2	—	—	—	—	—	—	—	—	—
Group III B										
31, Gallium	[2][8][18] 3	▯	—	—	4.5167	7.6448 (note c)			—	—
		a÷b÷c = 1:0.99868:1.69257, b=4.5107								
49, Indium	[2][8][18][18] 3	△	1.078	4,8	4.585±4	4.941±5	4 at 3.242	8 at 3.370	3.138	1
81, Thallium	[2][8][18][32][18] 3	α=○	1.600	6,6	3.450	5.520	3.404	3.450	3.427	—
		β=⊡	—	12	4.841	—	3.423	—	3.423	—

Notes: (a) ⧉ is body-centered cubic; ⊡ is face-centered cubic; ○ is close packed hexagonal; ▱ is simple rhombohedral; ▯ is orthorhombic; △ is face-centered tetragonal

(b) Appears to be smaller in some alloys.

(c) 8 atoms to unit cell; each atom has 1 neighbor at 2.437, 2 at 2.706, 2 at 2.733 and 2 at 2.799.

(f) Atomic diameters for new values have been computed by following Hume-Rothery's procedure whenever possible.

(g) See Page 580, Metal Progress, May 1941.

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Element Atomic No.	Electron Arrangement in Free Atoms	Crystal Structure (Note a)	Axial Ratio c÷a	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter Coordination No. 12 (Note f)	Reference (g)
Group IV A in Periodic Sequence										
22, Titanium	[2][8][10] 2	α = ○	1.601	6,6	2.95₃	4.72₉	2.91₅	2.95₃	2.93	—
	(slightly over 900°C.)	β = ▣	—	8	3.32	—	2.87₅	—	2.96	2
40, Zirconium	[2][8][18][10] 2	α = ○	1.589	6,6	3.22₃	5.12₃	3.16₆	3.22₃	3.19	—
	(data for 867°C.)	β = ▣	—	8	3.61	—	3.12₆	—	—	—
72, Hafnium	[2][8][18][32][10] 2	○	1.587	6,6	3.20₀	5.07₇	3.13₉	3.20₀	3.17	—
90, Thorium	[2][8][18][32][18][10] 2	▣	—	12	5.07₇ or 5.09₁	—	3.59₀ or 3.60₀	—	—	—
Group IV B, Including Carbon and Silicon										
6, Carbon, diamond	[2] 4	◇	—	4	3.560₈	—	1.511₃	—	—	—
graphite		○ (b)	2.75	6	2.46	6.78	1.42	2.46	—	—
14, Silicon	[2][8] 4	◇	—	4	5.417₃±₅	—	2.345₇	—	—	1
32, Germanium	[2][8][18] 4	◇	—	4	5.64₇	—	2.44₅	—	2.78₈	—
50, Tin, grey	[2][8][18][18] 4	◇	—	4	6.46	—	—	—	3.164	—
white		△	0.545₆	4,2	5.819₄	3.175₃	3.016₁	3.175₃	—	—
82, Lead	[2][8][18][32][18] 4	▣	—	12	4.938₉	—	3.492₃	—	3.494	—
Group V A in Periodic Sequence										
23, Vanadium	[2][8][11] 2	▣	—	8	3.033₈	—	2.627₄	—	2.69	1
41, Columbium	[2][8][18][12] 1	▣	—	8	3.294±₁	—	2.853	—	2.94	—
73, Tantalium	[2][8][18][32][11] 2	▣	—	8	3.295₉±₃	—	2.854₄	—	2.94	1
91, Protoactinium	[2][8][18][32][18][11] 2	—	—	—	—	—	—	—	—	—
Group V B										
7, Nitrogen	[2] 5	α = cubic	—	—	5.66	—	1.06	—	—	—
		β = hex.	1.63₃	—	4.03₄±₉	6.5₈₇±₁₆	—	—	—	1
15, Phosphorus, metallic	[2][8] 5	▯	a÷b÷c = 1 : 1.32 : 3.17		3.31	b=4.38 10.50	2.17	2.20	—	1
33, Arsenic	[2][8][18] 5	▱	α = 54°7.5′	3,3	4.13₅±₈	—	2.50₇	3.13₉	—	1
51, Antimony	[2][8][18][18] 5	▱	α = 57°6.5′	3,3	4.497₆±₂	—	2.879₅	3.378₄	3.228	1
83, Bismuth	[2][8][18][32][18] 5	▱	α = 57°14.2′	3,3	4.735₆±₆	—	3.103₆	3.472₈	3.64	1
Group VI A in Periodic Sequence										
24, Chromium	[2][8][13] 1	α = ▣	—	8	2.878₆	—	2.492₃	—	2.57	—
		β = ○	1.626	6,6	2.71₇	4.41₈	2.709	2.717	2.71	—
42, Molybdenum	[2][8][18][13] 1	▣	—	8	3.140₃	—	2.719₈	—	2.80	—
74, Tungsten	[2][8][18][32][12] 2	α = ▣	—	8	3.158₃	—	2.735₂	—	2.82	—
		β = cubic (c)	8 atoms in unit cell		5.038	—	2.519	2.816	—	—
92, Uranium	[2][8][18][32][13][12] 2	▯	4 atoms in unit cell; a:b:c = 1:2.056:1.734,		2.852	4.945 b=5.865	2.76	2.85	—	9
Group VI B										
8, Oxygen	[2] 6	α = ▯	4 atoms in unit cell; a:b:c = 1:0.691:0.625,		5.50	3.44 b=3.82	—	—	—	1
		β = ▱	α = 99.1°; 12 atoms in unit cell		6.19	—	—	—	—	1
		γ = cube	16 atoms in unit cell		6.83	—	—	—	—	1
16, Sulphur	[2][8] 6	α = ▯	128 atoms in unit cell; a:b:c = 1:1.233:2.343;		10.48	24.55 b=12.92	2.12	3.36	—	1
at 103°C.		(d) mono-clinic	a:b:c = 1:1.011:1.006; β = 83°16′;		10.90	10.96 b=11.02	—	—	—	7
34, Selenium	[2][8][18] 6	○ (e)	1.140	2,4	4.337	4.945	2.316	3.457	—	—
		monoclinic (α)	a:b:c = 1:0.998:1.281; 32 atoms in unit cell; β = 91°34′;		8.992	11.52 b=8.973	—	—	—	1
		monoclinic (β)	a:b:c = 1:6.311:7.261; 32 atoms in unit cell; β = 93°4′;		12.74	9.25 b=8.04	—	—	—	1
52, Tellurium	[2][8][18][18] 6	○ (e)	1.33	2,4	4.445	5.912	2.858	3.46	—	—
84, Polonium	[2][8][18][32][18] 6	pseudo hexagonal	3 atoms in pseudo cell		4.25	7.06 or 14.12	—	—	—	6
		probably monoclinic	a:b:c = 1:0.578:1.900; 12 atoms in unit cell; β = 92°;		7.42	14.10 b=4.29	3.4	4.0	—	6

Notes: (a) ▣ is body-centered cubic; ▣ is face-centered cubic; ○ is close packed hexagonal except as noted; ◇ is diamond; △ is tetragonal; ▱ is rhombohedral, and ▯ is orthorhombic.

(b) Graphite is hexagonal, not close packed, with four atoms per unit cell.

(c) Cubic structure; two positions distinguishable, X and Y. Each atom X has 12 Y at 2.816 Å; each atom Y has 2 Y at 2.519 and 4 X at 2.816 Å.

(d) Unit cell contains 48 S or 6 S₈.

(e) Hexagonal, not close packed; each atom has 2 neighbors at d_1 and 4 at d_2.

(f) Atomic diameters for new values have been computed by following Hume-Rothery's procedure whenever possible.

(g) See Page 588, Metal Progress, May 1941.

Crystallography of the Chemical Elements

As Tabulated by William Hume-Rothery
in "The Structure of Metals and Alloys," Monograph No. 1, British Institute of Metals.

Emendations (by H.C. Vacher) represent values that have appeared in the literature from 1936 to 1940 inclusive.

Element Atomic No.	Electron Arrangement in Free Atoms	Crystal Structure (Note a)	Axial Ratio c÷a	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter Coordination No. 12 (Note f)	References (g)
Group VII A in Periodic Sequence										
25, Manganese	[2][8][13] 2	α = cubic (note b)	—	—	8.894	—	—	—	—	—
		β = cubic (note c)		12	6.300	—	—	—	—	—
		γ = △	0.934	—	3.774	3.526	2.582	2.669	—	—
43, Masurium	[2][8][18][14] 1	—	—	—	—	—	—	—	—	—
75, Rhenium	[2][8][18][32][18] 2	○	1.614 8	—	2.755 3	4.449 3	2.734 9	2.755 3	2.75	—
Group VII B										
9, Fluorine	[2]7	—	—	—	—	—	—	—	—	—
17, Chlorine	[2][8]7	△	0.715	—	8.56	6.12	1.88 (note e)	—	—	4
			16 atoms in unit cell							
35, Bromine	[2][8][18]7	□	a:b:c = 1:1.49:1.95		4.48	8.72	2.27	noted	—	5
			8 atoms in unit cell; b = 6.67							
53, Iodine	[2][8][18][18]7	□	a:b:c = 1:1.51:2.04		4.795	9.780	2.70	noted	—	—
			8 atoms in unit cell; b = 7.255							
85, Alabamine	[2][8][18][32][18] 7	—	—	—	—	—	—	—	—	—
Group VIII in Periodic Sequence										
26, Iron	[2][8][14] 2	α = ⧉	—	—	2.861	—	2.477 7	—	—	—
		β = ⊡	—	—	3.64 at 900°C.	—	2.58 0	—	2.52	—
27, Cobalt	[2][8][15] 2	α = ○	1.624	—	2.50 7	4.07 2	2.49 9	2.50 7	2.50	—
		β = ⊡	—	—	3.54 5	—	2.50 7	—	2.50 7	—
28, Nickel	[2][8][16] 2	α = ○	1.64	—	2.49	4.08	2.49	2.49	2.49	—
		β = ⊡	—	—	3.517 0	—	2.486 9	—	2.48 7	—
44, Ruthenium	[2][8][18][15] 1	○	1.583	—	2.698 4	4.273 0	2.644	2.698	2.67	8
45, Rhodium	[2][8][18][16] 1	⊡	—	—	3.795 5	—	2.683 8	—	2.684	—
46, Palladium	[2][8][18][18]	⊡	—	—	3.882 4	—	2.745 3	—	2.745	—
76, Osmium	[2][8][18][32][14] 2	○	1.579	—	2.7298	4.310 4	2.670	2.730	2.70	8
77, Iridium	[2][8][18][32][15] 2	⊡	—	—	3.831 2	—	2.709 1	—	2.709	—
78, Platinum	[2][8][18][32][16] 2	⊡	—	—	3.915 8	—	2.768 9	—	2.769	—
Rare Earth Group										
58, Cerium	[2][8][18][19][9] 2	α = ○	1.62	6,6	3.65	5.91	3.63	3.65	3.64	—
		β = ⊡	—	12	5.14 3	—	3.63 7	—	3.63 7	—
59, Praseodymium	[2][8][18][20][9] 2	○	1.620	6,6	3.65 7	5.924	3.63 8	3.65 7	3.65	—
60, Neodymium	[2][8][18][21][9] 2	○	1.608	6,6	3.65 7	5.8 8	3.61 9	3.65 7	3.64	—
67, Holmium	[2][8][18][28][9] 2	○	1.580	6,6	3.55 7 ± 3	5.62 0 ± 5	3.48 0	3.55 7	3.52	11
68, Erbium	[2][8][18][29][9] 2	○	1.63	6,6	3.74	6.09	3.73	3.74	3.73	—

Notes: (a) ⧉ is body-centered cubic; ⊡ is face-centered cubic; ○ is close packed hexagonal; □ is orthorhombic; △ is tetragonal.

(b) Approximates ⧉ where each lattice point is a cluster of 29 atoms; 1 type X, 4 type A, 12 type D_2 and 12 type D_1. The X atoms occupy the largest volume and the D_2 the smallest. Interatomic distances of neighboring atoms are as follows:

X atoms have: 12 D_2 at 2.71; 4 A at 2.82

A atoms have: 1 X at 2.82; 3 D_1 at 2.49 and 3 at 2.96; 3 D_2 at 2.69 and 3 at 2.89

D_2 atoms have: 1 X at 2.71; 2 A at 2.69 and 1 at 2.89; 1 D_2 at 2.24 and 2 at 2.38; 1 D_1 at 2.45, 2 at 2.51 and 2 at 2.66

D_1 atoms have: 1 A at 2.49 and 1 at 2.96; 1 D_2 at 2.45, 2 at 2.51 and 2 at 2.66; 6 D_1 at 2.67

(c) Complicated structure with 20 atoms of two kinds in unit cell. Each atom of the first kind has:

3 neighbors at 2.365
3 " " 2.530
3 " " 2.671
3 " " 2.675

Each atom of the second kind has: 2 neighbors at 2.530
2 " " 2.615
4 " " 2.659
2 " " 2.671
2 " " 2.675

(d) Atoms arranged in pairs so that each one has one close neighbor at a distance d_1.

(e) The authors give 1.99 as the closest approach to a neighboring atom, however, they did not indicate clearly the space group. If the space group is D_{2h}^{16} with 16 atoms to a unit cell and the X, Y, and Z perameters are 0.125, 0.167 and 0.107, respectively, then d_1 = 1.88.

(f) Atomic diameters for new values have been computed by following Hume-Rothery's procedure whenever possible.

(g) See Page 580, Metal Progress, May 1941.

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Physical Constants of Purest Zinc

(Compiled by Research Division, New Jersey Zinc Co.)

Note: Purity stated is that reported for metal used in preparing test pieces; actual composition of latter is infrequently given

Constants Affected by Orientation

Unit Cell Dimensions (Angstrom Units)

Reference:	13	2
Purity:	Spectroscopic	99.99+%
Temperature:	25°C.	27°C.
a	2.6597	2.6600±0.0002
c	4.9367	4.9379±0.0005
c÷a	1.8561	1.8563

Coefficient of Expansion

Reference:	8		4	
State:	Single Crystal		Polycrystalline Casting	
Purity:	Spectroscopic	Kahlbaum's Best[a]	99.993%	
Direction:	44° to Principal Axis	0° to Principal Axis		
0 to 50°C.	4.00×10⁻⁵	[b] 5.46×10⁻⁵		
0 to 100	4.04	5.70	20 to 100	3.95×10⁻⁵
0 to 150	4.23	5.74	20 to 150	3.96
0 to 200	4.40	5.80	20 to 200	3.97
0 to 250	4.55	5.81	20 to 250	3.97
0 to 300	4.60	5.73		

[a] Contains 0.014% Pb, 0.012% Cd
[b] Reference 9 gives 5.74 at 18°C., and 1.26 for perpendicular direction

Thermal Conductivity

Reference: 7
State: Single Crystal
Purity: 99.993%

Temp.	Cal./sec./cm./°C.
-200°C.	0.36
-150	0.34
-100	0.33
-50	0.32
0	0.30
+50	0.29
+100	0.28

Magnetic and Electrical Properties

	Magnetic Susceptibility		Resistivity (ohms/cu.cm.)		Temp. Coefficient of Resistivity	
Reference:	10		11		4	12	4
State:	Single Crystal		Single Crystal		Swaged Polycrystalline Wire	Single Crystal	Wire, Swaged and Drawn
Purity:	Chemical		Spectroscopic		Spectroscopic	Spectroscopic	
Direction:	0° to Hexagonal Axis	90° to Hexagonal Axis	0° to Hexagonal Axis	90° to Hexagonal Axis		1° to 86.5° to Principal Axis	
Temp. Constant	— -1.90×10⁻⁷	— -1.45×10⁻⁷	20°C. 6.16×10⁻⁶	20°C. 5.83×10⁻⁶	20°C. 5.916×10⁻⁶	-170 to 25°C. 4.058×10⁻³ (average)	0 to 100°C. 4.19×10⁻³

Constants Not Known to Be Affected by Orientation

Thermal Electromotive Force (Zn-Pt Thermocouple)

Reference: 4
State: Cold Drawn Wire
Purity: Spectroscopic

Temp.	Millivolts
0°C.	0.000
50	0.331
100	0.758
150	1.276
200	1.894
250	2.610
300	3.417
350	4.310
400	5.290
415	5.604

Specific Heat

Reference: 6
Purity: 99.948%

Temp.	Cal./g./°C.
100°C.	0.0946
200	0.0961
300	0.0981
400	0.1002
500	0.1522
600	0.1473
700	0.1444
800	0.1423

Density, Melting and Boiling Points

State	Purity	Temp.	Density g./cu.cm.	Reference
Density:				
Cast	99.993%	25°C.	7.131	3
Rolled	99.993%	25	7.142	2
Swaged wire	Spectroscopic	25	7.133	4
Molten	99.94%	419.4	6.92	2
Melting Point	Spectroscopic	419.47	—	4
	Spectroscopic	419.45	—	2
	99.993%	419.48	—	5
Boiling Point at 760 mm. pressure		905°C.±2	—	1

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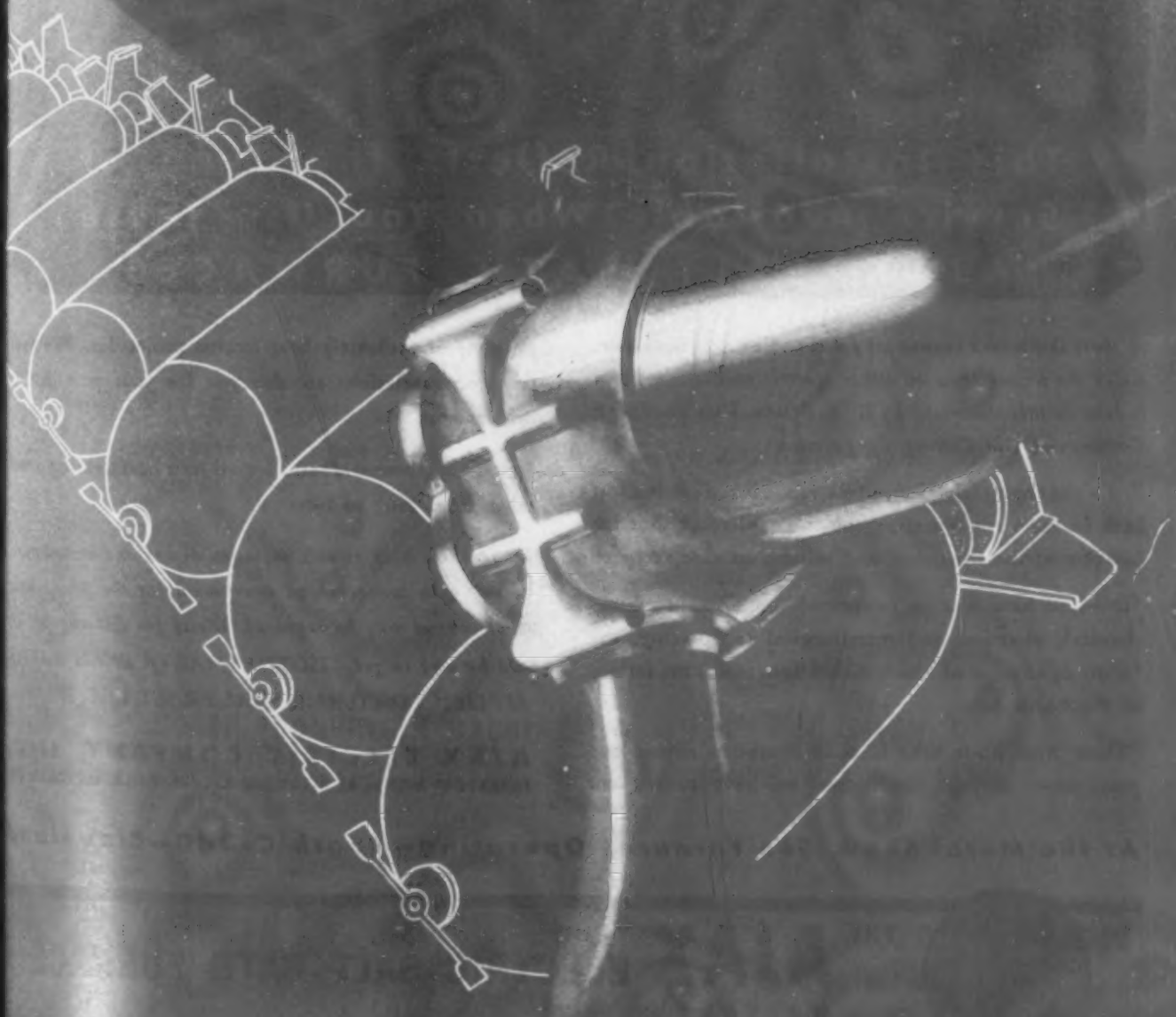

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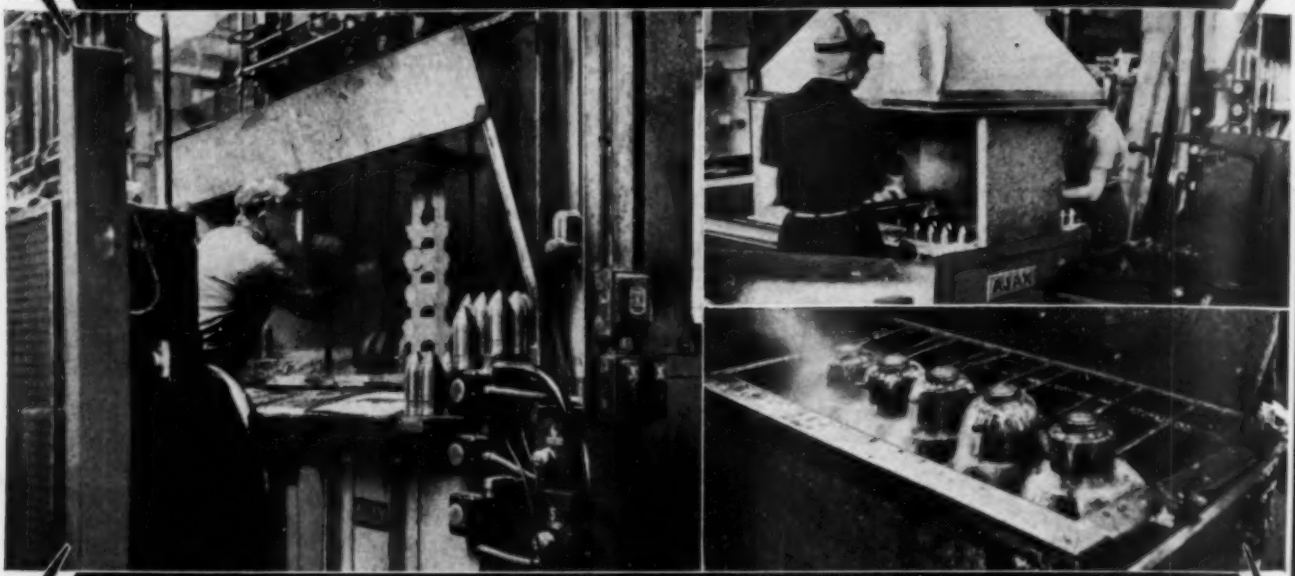

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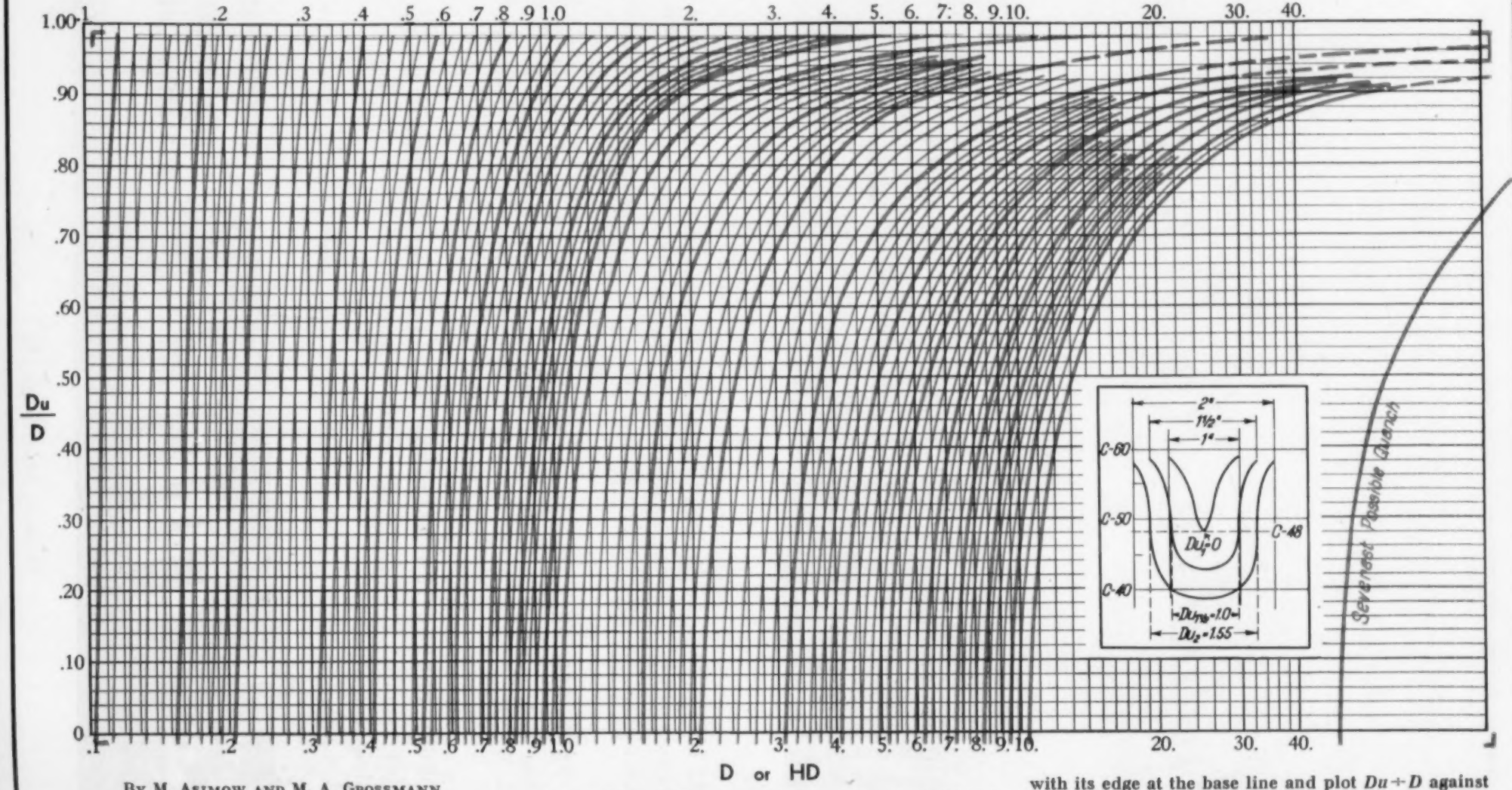
Cooling Power of Quenching Baths

Curves whereby severity of quench (heat transfer equivalent H) can be estimated. Copyright, 1939, Carnegie-Illinois Steel Corp.



By M. Asimow and M. A. Grossmann

TO USE this chart, harden *at least* three bars of various diameters in the given medium at working temperature and circulation, and determine curves of hardness distribution, edge to axis, at mid-length. In the example sketched in the inset above, D is 1, 1.5 and 2 in. respectively. At a selected hardness horizontal, as C-48, which intersects or touches all curves, determine the ratio $Du \div D$ between soft center and bar diameter. (Soft center diameter Du is 0, 1.0 and 1.55 in.; $Du \div D$ is 0, 0.66 and 0.77 respectively.) Lay a piece of tissue paper over the chart with its edge at the base line and plot $Du \div D$ against D for each bar size. Slide tissue paper right or left until these points fall on a single curve, which for this quench happens when D_1 is at 5.0 and $D_{1.5}$ is at 7.5 (these now being values of HD). Then H, the severity of this quenching set-up, is $HD \div D$ or $5.0 \div 1.0$ or 5.0 (or $7.5 \div 1.5$ which gives the same result).

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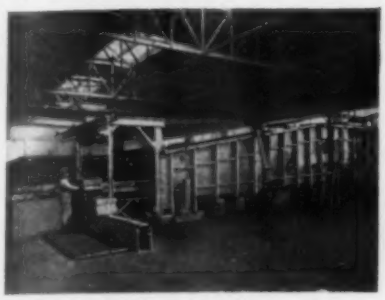
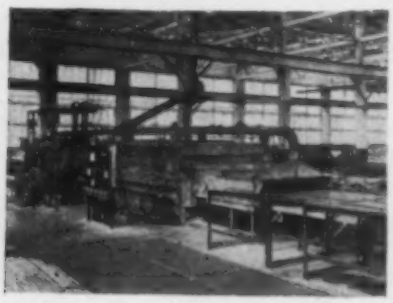
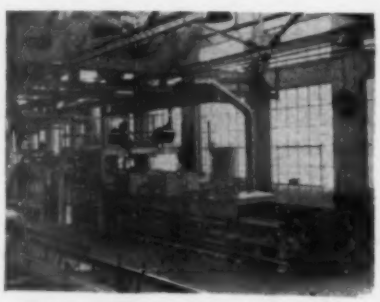


Heating Brass Cakes — Large pusher type, oil fired furnace, automatically operated.

Heating Copper Wire Bars — Automatic gas fired furnace, with cycle control from rolling mill pulpit.

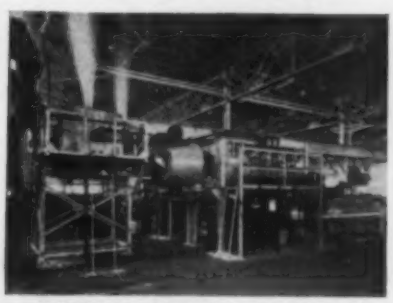


Annealing Slabs — Continuous roller hearth, gas fired furnace with controlled atmosphere.

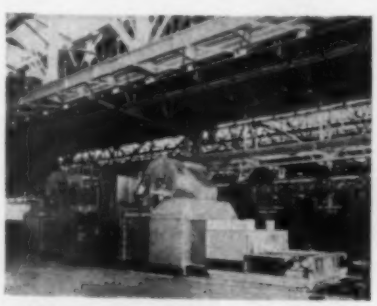


Bright Annealing Copper Tubing — Belt conveyor, gas fired, muffle furnace with controlled atmosphere.

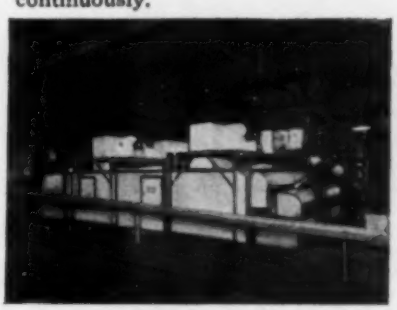
Washing, Annealing, Pickling and Drying Brass Stampings — Equipment and furnace operate continuously.



Washing, Annealing and Pickling Small Pieces — Continuous rotary cleaning machines and gas furnace.



Heating Aluminum Billets — Four row conveyor furnace, recirculating convection type.



Drawing Shells — Belt conveyor, electric furnace, two zone recirculating convection heating.

Heating Aluminum Castings — Automatic elevator type electric furnaces and quench tanks.

ROCKWELL SINCE 1888 BUILT

FOR BETTER PERFORMANCE

ROCKWELL *Industrial* **FURNACES**

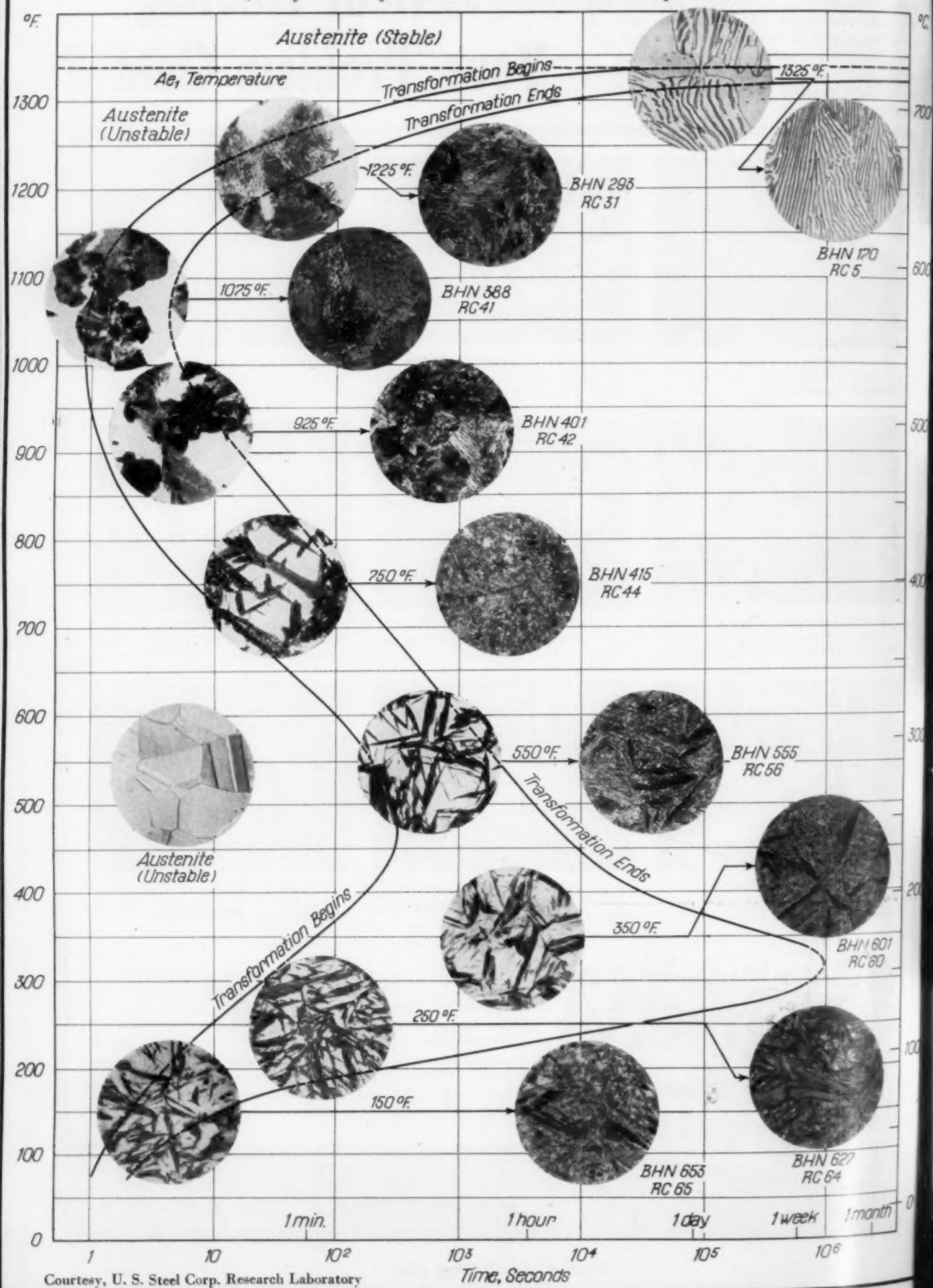
Whether it is in a continuous or intermittent operation, a Rockwell Furnace assures you of controlled uniformity of heating and cooling, at the same temperature throughout, in the same atmosphere, at the required production rate, at all times. It's all in the "know-how", and thousands of Rockwell Furnaces in action prove that. Let Rockwell furnace engineering help lick your next heat treating problem.

W. S. ROCKWELL COMPANY

46 CHURCH STREET NEW YORK 7, N. Y.

S-Curve for 0.89% Carbon Steel

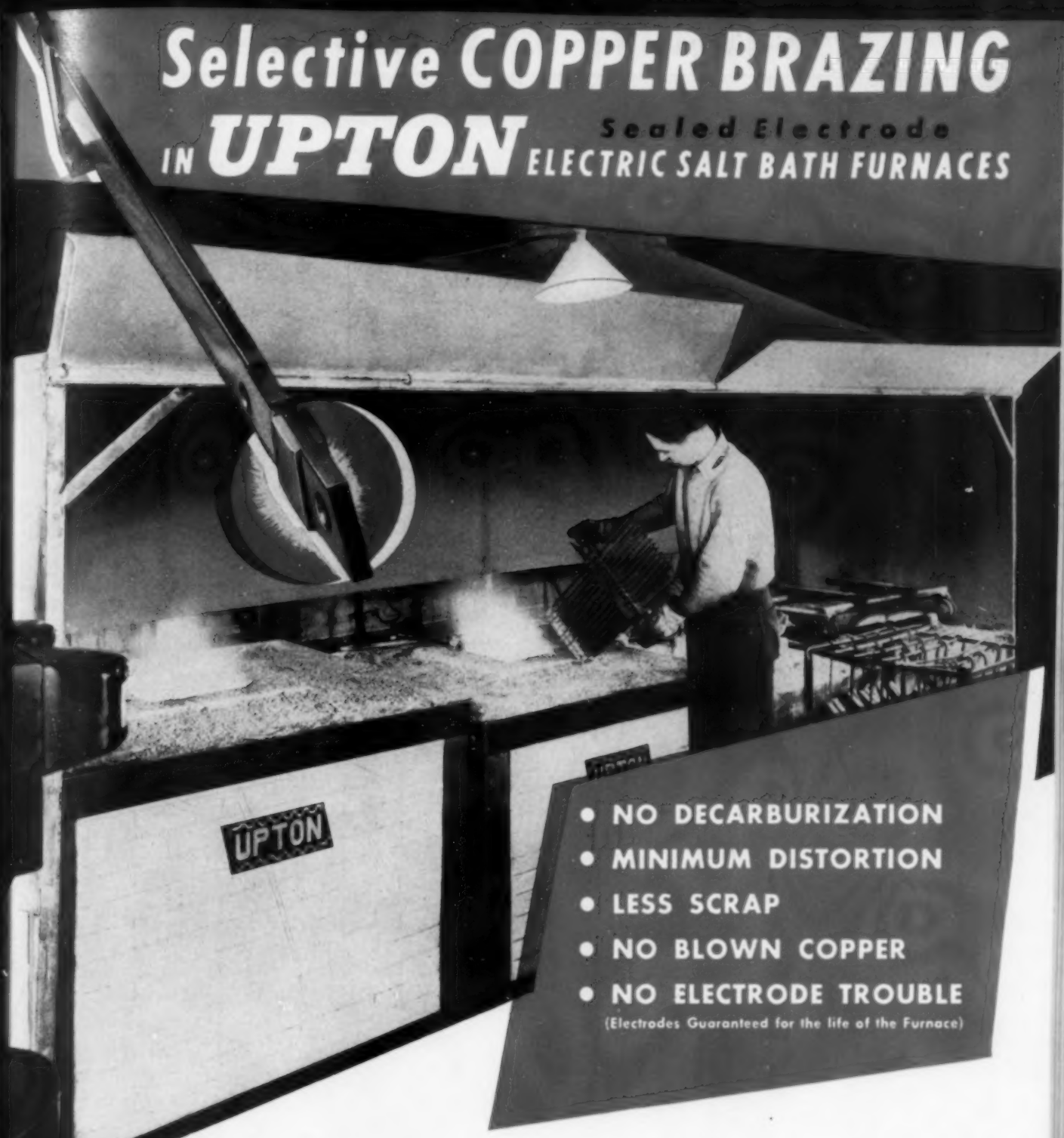
(Transformation of austenite at constant sub-critical temperature)



Courtesy, U. S. Steel Corp. Research Laboratory

Selective COPPER BRAZING

IN UPTON Sealed Electrode ELECTRIC SALT BATH FURNACES



Selective Brazing of ordnance part subjected to intense impact is being handled at high speeds in Upton Electric Salt Bath Furnaces.

Complete absence of any noticeable decarburization permits re-hardening following the brazing operation. The selective brazing practical only in the salt bath furnace eliminates most of the distortion found in other processes. The salt quench stops the flow of copper, but does not cause it to "blow" or form a blob on the surface.

These same furnaces, in the shop of a commercial heat treating concern, are being used, alternately, for high speed steel hardening and copper brazing.

When inquiring for additional information, please give complete details on your problem so that our answer to you can be complete.

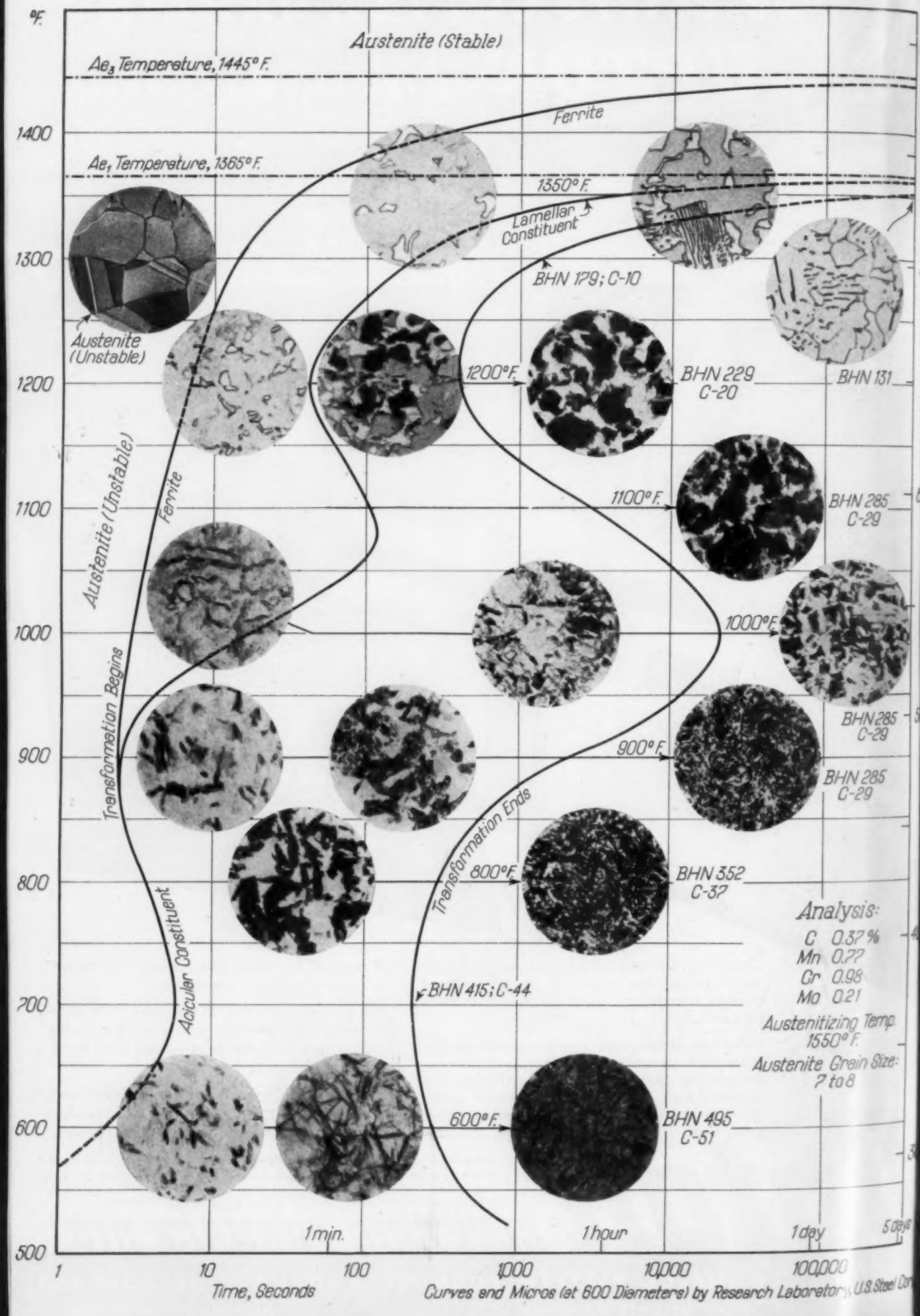
See a battery of Upton furnaces in operation. In Detroit there is an installation of Upton Electric Salt Bath Furnaces kept in operation for your inspection. You are cordially invited to inspect this installation to see the type of work possible only with an Upton Electric Bath Furnace.

Upton ELECTRIC FURNACE DIV.

COMMERCE PATTERN FOUNDRY AND MACHINE COMPANY

7435 MELVILLE AT GREEN DETROIT 17, MICHIGAN

S-Curve for S.A.E. 4140 Steel



Curves and Micros (at 600 Diameters) by Research Laboratory, U.S. Steel Corp.

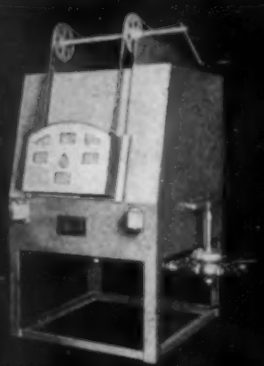
STEWART

THE BEST INDUSTRIAL FURNACES MADE

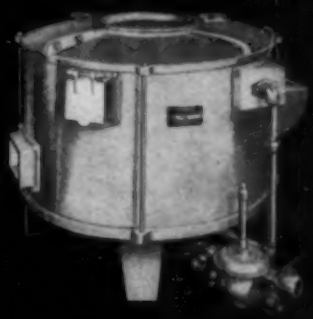
A TYPE FOR EVERY NEED

In addition to large units designed to meet specific production requirements, STEWART also builds these famous

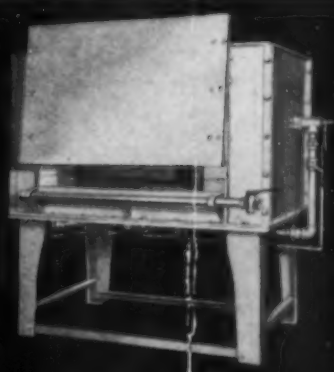
STANDARD INDUSTRIAL FURNACES



SEMI-MUFFLE OVEN FURNACE

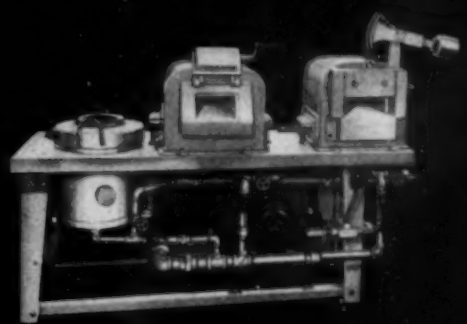


ROUND POT FURNACE



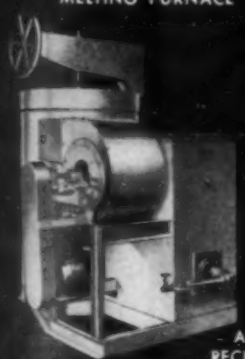
OPEN SLOT FORGE

STATIONARY METAL MELTING FURNACE

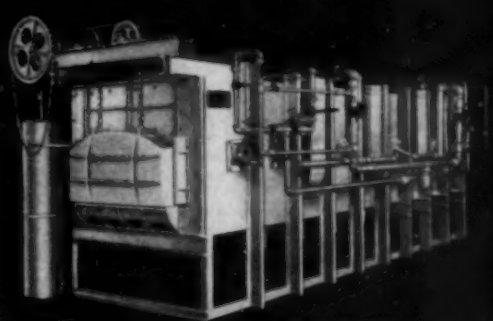


TRIPLE PURPOSE COMBINATION

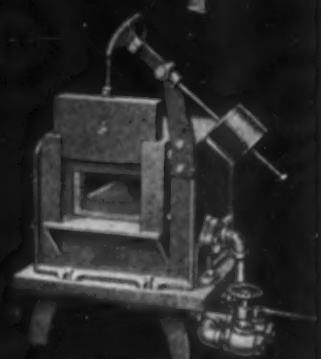
SMALL FORGE



AIR DRAW RECIRCULATING FURNACE



HEAVY PORTABLE OVEN FURNACE



BENCH OVEN FURNACE

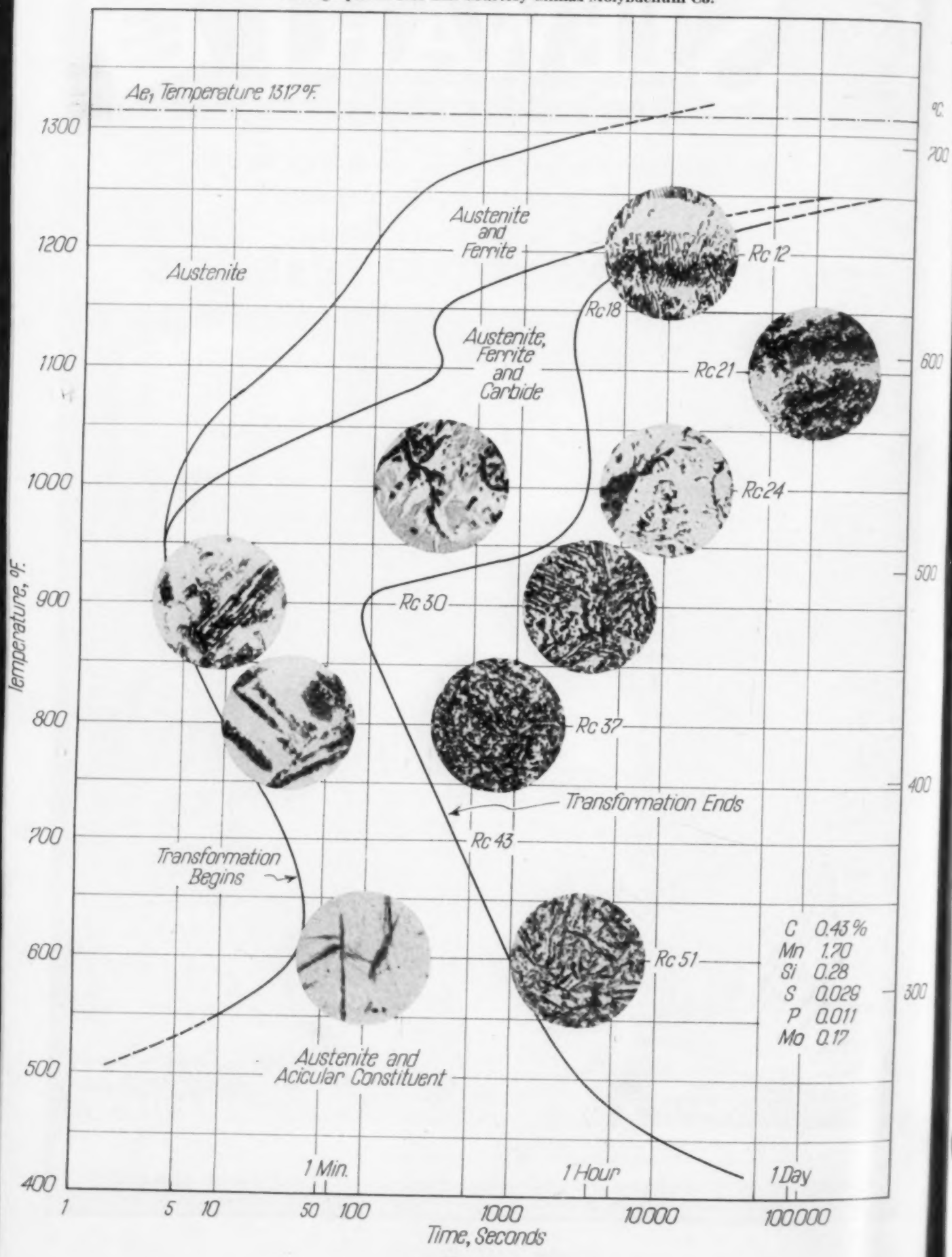
A letter, wire or 'phone call will promptly bring you information and details on STEWART Furnaces. Or, if you prefer, a STEWART engineer will be glad to call and discuss your heat-treating problems with you.

STEWART INDUSTRIAL FURNACE DIVISION OF CHICAGO FLEXIBLE SHAFT COMPANY

Main Office: 5600 W. Roosevelt Road, Chicago 50, Ill.—Canada Factory: (FLEXIBLE SHAFT CO., LTD.) 321 Weston Rd., So., Toronto

S-Curve for Manganese (Low Molybdenum) Steel

Austenizing Temperature: 1550 °F. Austenite Grain Size: 7 to 8.
Micrographs at 1000 dia. Courtesy Climax Molybdenum Co.



Factory Trained

LEPEL ENGINEERING SERVICE IS CLOSE AT HAND...

An important tenet of Lepel's policy of service to users of induction heating is to be able to offer, at all times and in all centers of industry, readily-available sales and engineering service equal to that enjoyed by companies served from the home office.

To this end, Lepel has exercised great care in the choice of its representatives outside the New York area, selecting only organizations of outstanding reputation and staffing them with engineers specially-trained in the Lepel plant according to Lepel's high engineering standards.

These organizations, well-known to industries in their territories whose confidence they have won through honorable dealings and dependable service, offer competent engineering advice to users of induction heating and those who contemplate its use. Call on them for any information on the subject.

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   San Francisco 7, Calif., 844-54 Folsom Street
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   Covering California, Nevada and Arizona.

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   Telephone Atlantic 2220
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PIONEERS IN INDUCTION HEATING

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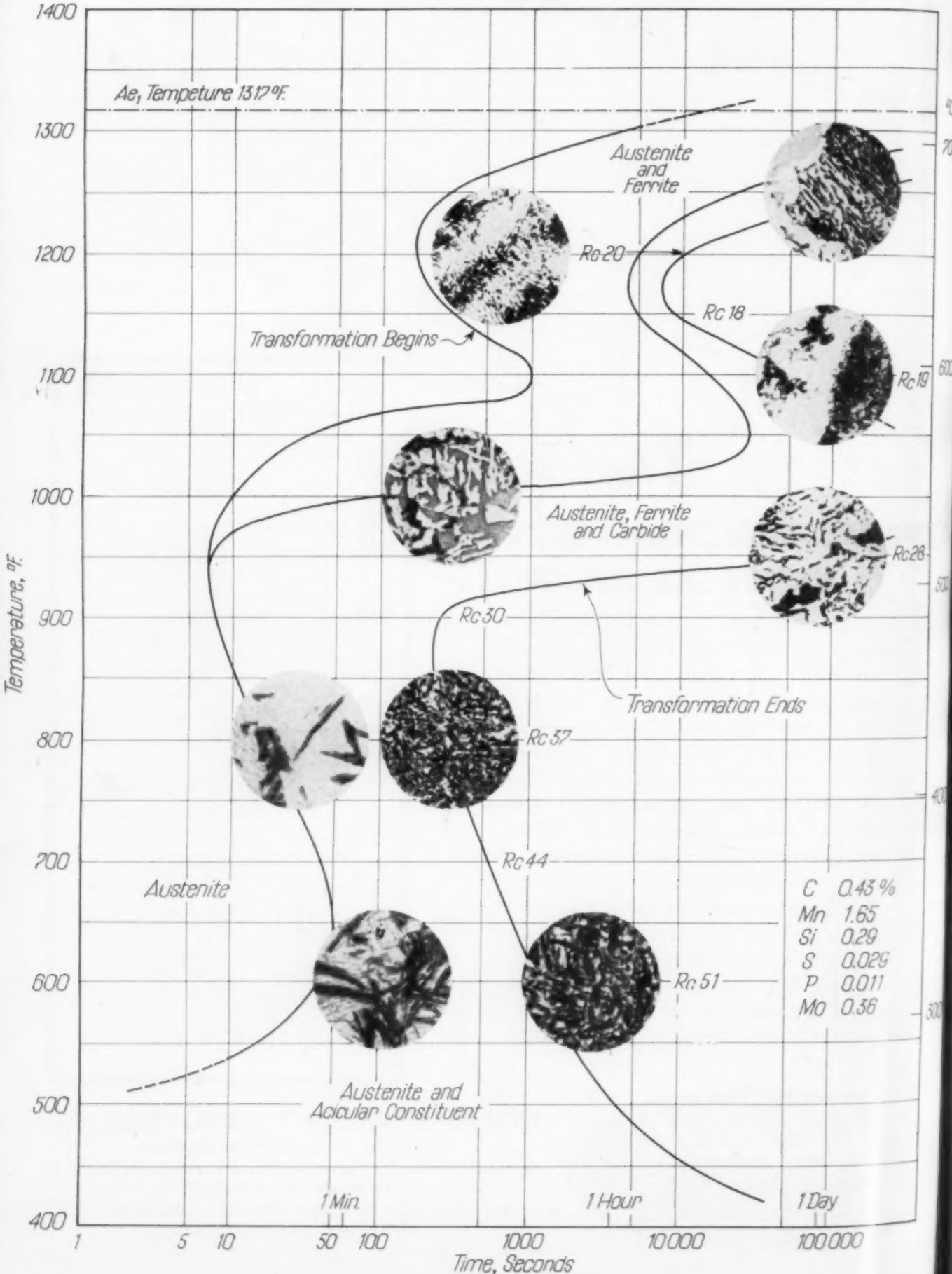
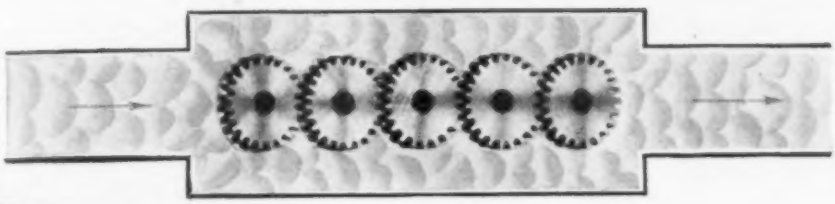
***Chicago Office:* 230 East Ohio Street, Chicago, Ill.**
Telephone: WHitehall 8483

S-Curve for Manganese (High Molybdenum) Steel

Austenizing Temperature: 1550°F. Austenite Grain Size: 8.
Micrographs at 1000 dia. Courtesy Climax Molybdenum Co.



Controls at the Work



HEATING OF ALL STEELS

EUTECTOID CARBURIZING

RESTORATION

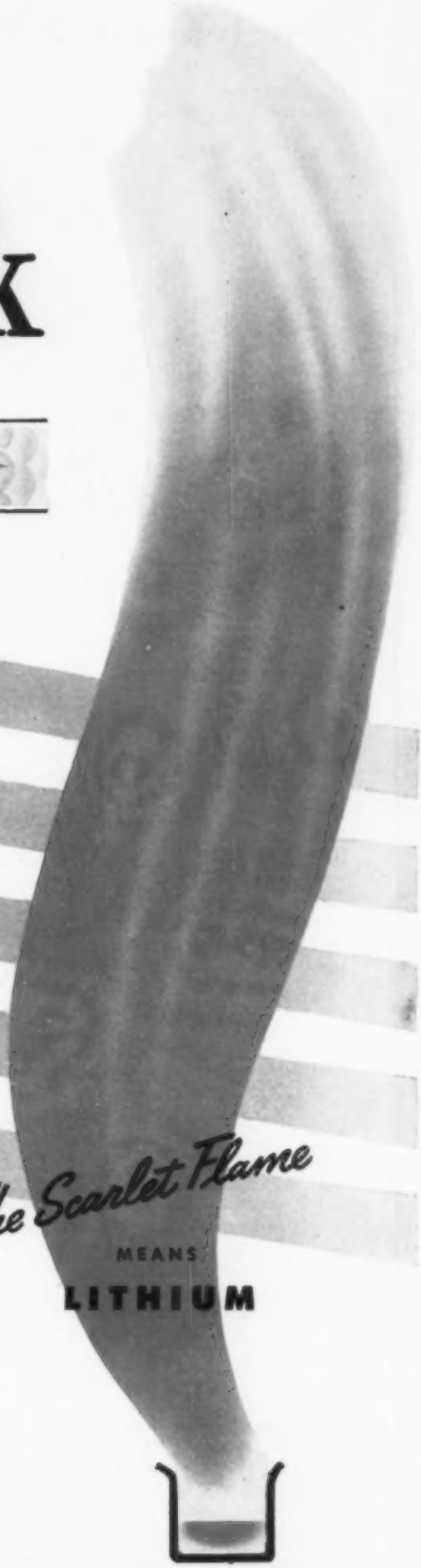
FLUID BRAZING

AND DESCALING

THE LITHIUM COMPANY

Manufacturers of Lithium Atmosphere Furnaces

111 SYLVAN AVE., NEWARK 4, N. J.



The Scarlet Flame

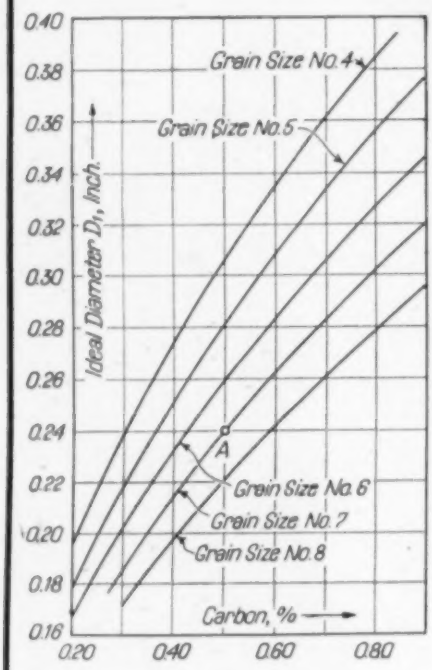
MEANS

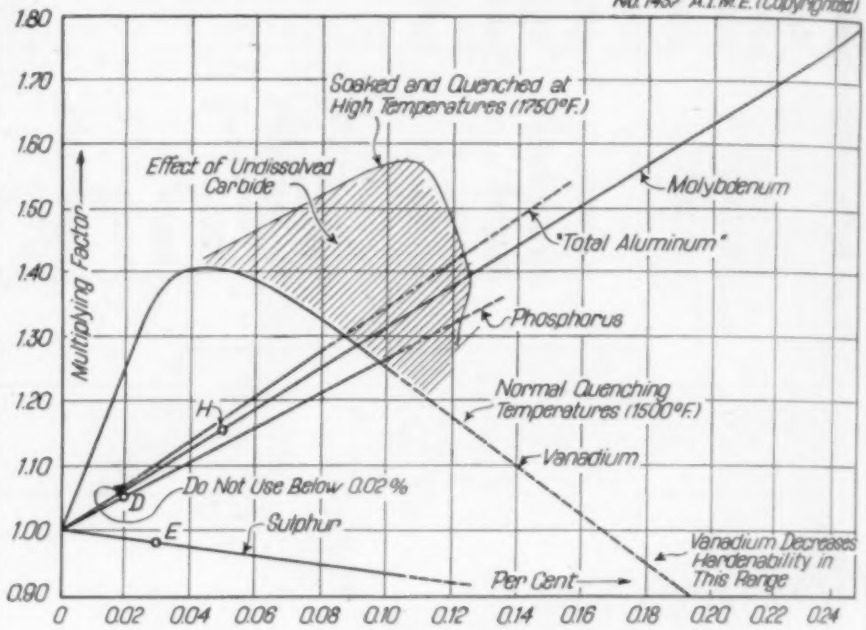
LITHIUM

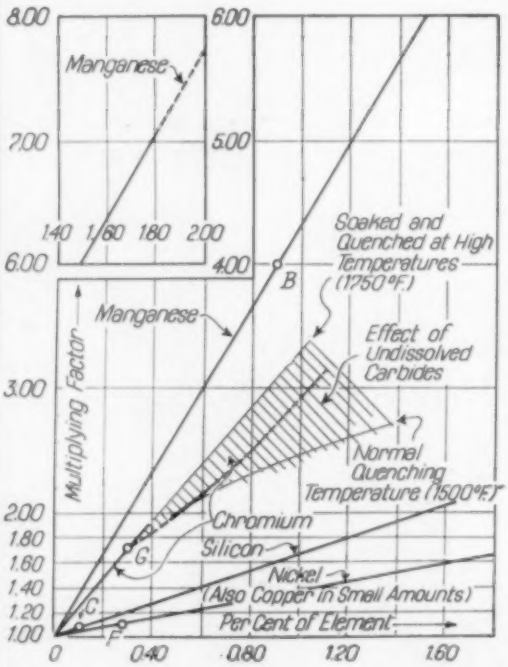
Hardenability Calculated From Composition

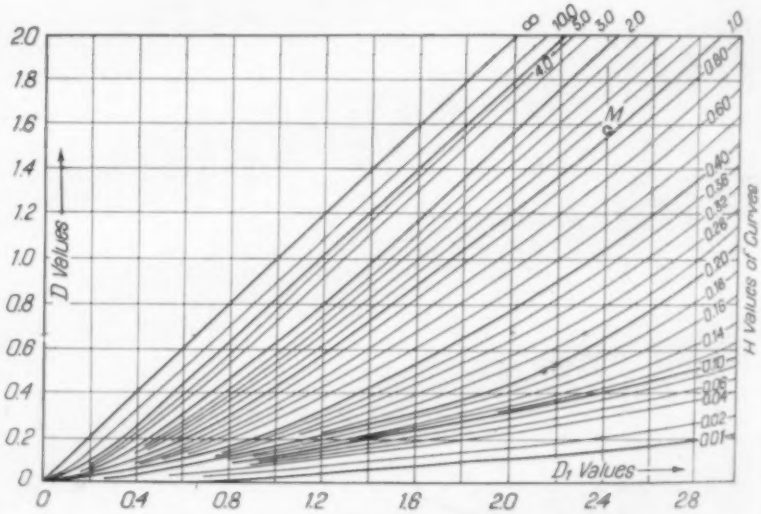
By Marcus A. Grossmann

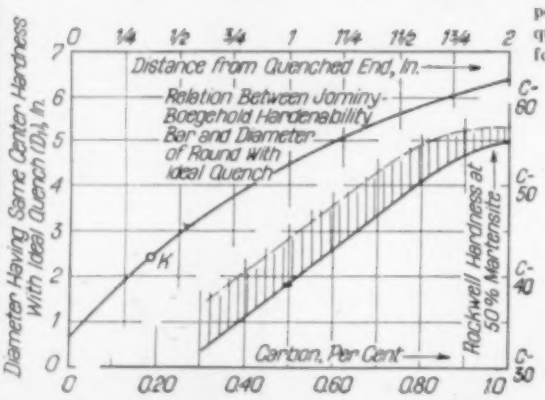
From Technical Publication No. 1437 A.I.M.E. (Copyrighted)










Distance from Quenched End, In.
Relation Between Jominy-Boegehold Hardenability Bar and Diameter of Round with Ideal Quench
K
Diameter Having Same Center Hardness With Ideal Quench (D_1), In.
Rockwell Hardness at 50% Martensite
Carbon, Per Cent

Example: To compute hardenability of a commercial steel of the analysis shown:

Item	Amount	Factor	Point
Grain size	7	0.24	*A*
Carbon content	0.50		
Manganese	0.90	4.00	*B*
Silicon	0.10	1.10	*C*
Phosphorus	0.020	1.05	*D*
Sulphur	0.029	0.96	*E*
Nickel	0.28	1.16	*F*
Chromium	0.30	1.70	*G*
Molybdenum	0.05	1.16	*H*
Copper	0.05	1.02	*

*Estimated on the line for nickel.

Ideal hardenability of given steel = D_1 = $0.24 \times 4 \times 1.1 \times 1.05 \times 0.98 \times 1.1 \times 1.7 \times 1.16 \times 1.02$ = 2.40. Such figures for D_1 will accurately compare one steel with another.

Jominy equivalent of the given steel at point *K*, that is, hardness of center of ideally quenched 2.40-in. bar, is the same as that found 3/8-in. from end of end-quenched specimen.

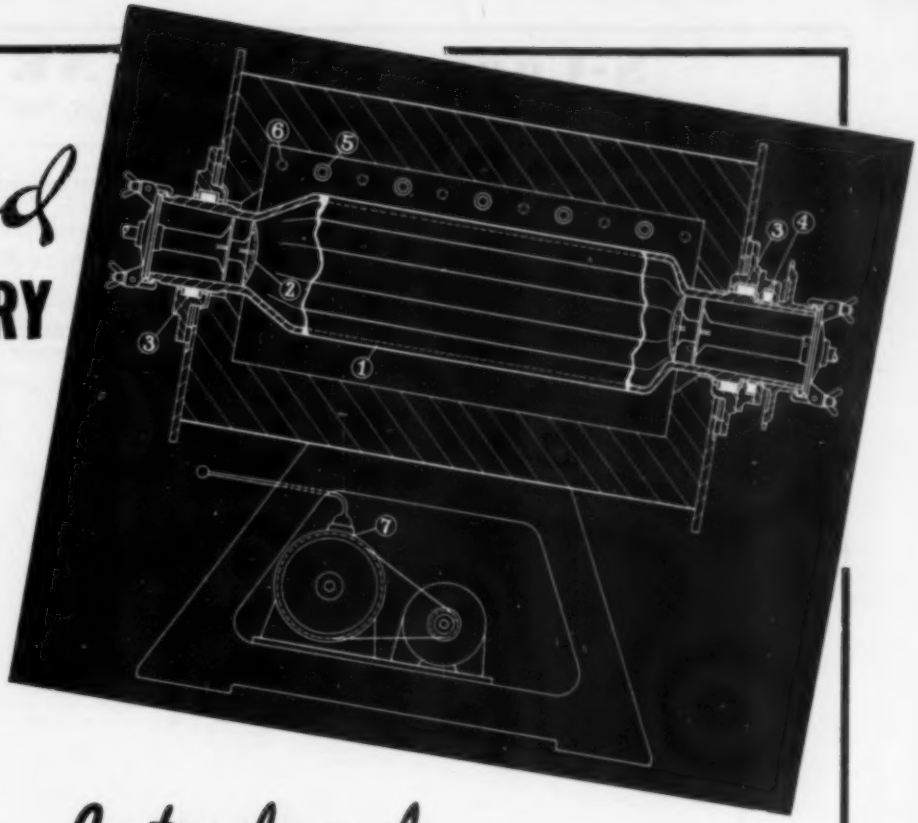
Actual hardness at center, taken from lowest curve, is about C-45 for 0.50 carbon, low alloy steel.

Quenching power H of commercial baths may be determined by methods shown in the data sheet, Metal Progress, Oct. 1941, page 520, or estimated from the table at right, below.

Circulation or Agitation	Value of H for Oil	Water	Brine
None	0.25 to 0.30	0.9 to 1.0	2
Mild	0.30 to 0.35	1.0 to 1.1	2 to 2.2
Moderate	0.35 to 0.40	1.2 to 1.3	.....
Good	0.4 to 0.5	1.4 to 1.5	.....
Strong	0.5 to 0.8	1.6 to 2.0	.....
Violent	0.8 to 1.1	4	5

Example: Water quench, mildly agitated; H = 1.05; Steel D_1 = 2.40. Actual critical diameter D (from point *M* above D_1 = 2.40) is $1\frac{3}{16}$ in., size of bar of given steel that will harden in given quench to half martensitic structure at center; hardness C-45.

Improved
No. 2GA ROTARY CARBURIZER



This machine is the modern counterpart of our long popular No. 2-B size Carburizer.

It embodies all the most prominent advantages of Rotary Carburizers, which are as follows:

- May be used for atmosphere work without modification.
- Mixing by rotation insures uniformity.
- Charging and discharging labor is minimized by the tilting feature.
- Work may be quenched or slow cooled, as desired.
- Maintenance and handling of boxes is eliminated.

Introduced at the Metals Show

• BOOTH B103 •

1. Twelve-sided retort reduced at both ends is especially suited for handling small articles. The smaller entrance permits a more gradual and thus better discharge for quenching. The new construction permits preheating the carburizing gas before entering the work chamber, thus resulting in more uniform carburizing.

2. Improved small area spacing disc is easier to heat rapidly and uniformly and is much lighter and convenient to handle when charging and discharging.

3. Retort is supported on alloy roller bearings front and rear. This maintenance-free construction permits smooth and continuous rotation with the least amount of power.

4. New roller thrust bearing carries load smoothly in tilted position.

5. New design heat-resisting alloy burners with greater radiating surface are cooler in operation and are clayed into improved refractory tunnels.

6. Burners are arranged in two sections to heat work rapidly and uniformly to carburizing temperature. One section may be shut off to operate uniformly at temperatures as low as 1000° F. for clean hardening, annealing, high drawing, etc.

7. Different classes of work are accommodated by a motor drive with gear shift transmission which gives retort speeds of ¼, ½, 1 and 1½ r. p. m.

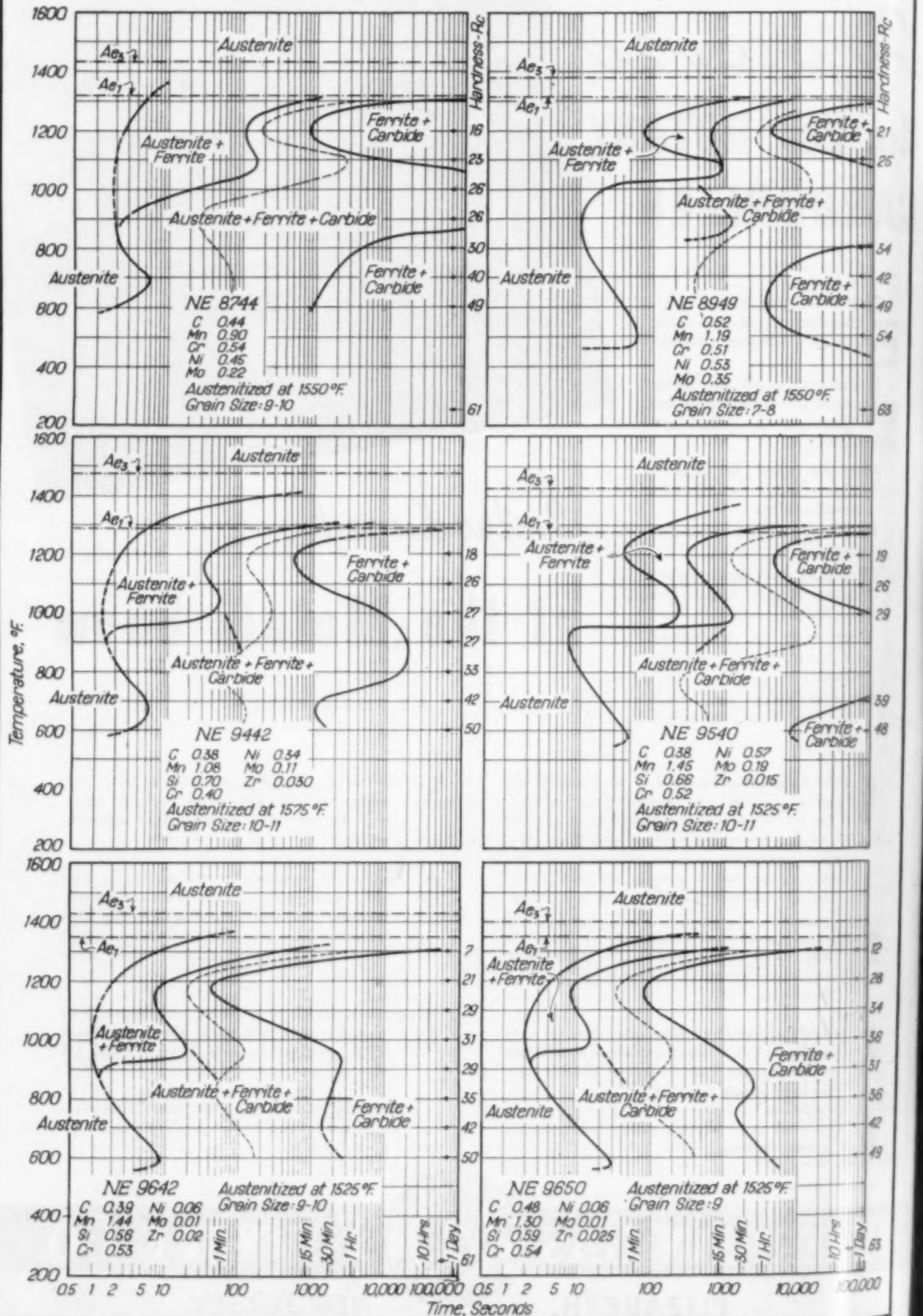
Write for literature on the new Carburizer and ask for our complete Condensed Catalog No. 604.

AMERICAN GAS FURNACE CO.

ELIZABETH, NEW JERSEY.

S-Curves for Six NE Steels

Isothermal Transformation Diagrams Determined by U. S. Steel Corp. Research Laboratory



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Inhibited oils and greases that give full protection to metal surfaces. Types that meet, and exceed, government specifications, including drying, non-drying, grease-type, waxy film, thin-film polar type, wax coating, etc. Write for the new Houghton manual on rust prevention.

TON LINE

COOLANTS FOR MACHINING

A complete series of scientifically fortified cutting oils and bases featuring the new "ALL-Purpose" Cutting Base, miscible with either oil or water. Also grinding compounds, thread grinding oils, and transparent soluble cutting oils.

METAL PROCESSING

Drawing compounds (HOUGHTO-DRAW) to lubricate dies and work for all types of stamping, drawing and forming. For lubricating forging dies — Hot Forging Agents and Houghton's DIE-SLICK. Also wire-drawing agents, metal cleaners, core binders, tempering oils, pot-type carburizers, inhibitors—a complete line of processing products for the metal industry.

SERVICE . . .

Houghton is justly proud of the personalized aid rendered by its engineering staff—men who can recommend a process and make it work—men who are on call at all times in all sections of the country. "Shirt-sleeved Research", we call it, backed by an augmented laboratory staff and 79 years of accumulated experience. All this as a "plus" value for the products listed herein, to help you solve reconversion problems.

E. F. HOUGHTON & CO.

303 W. Lehigh Ave., Phila. 33, Pa.

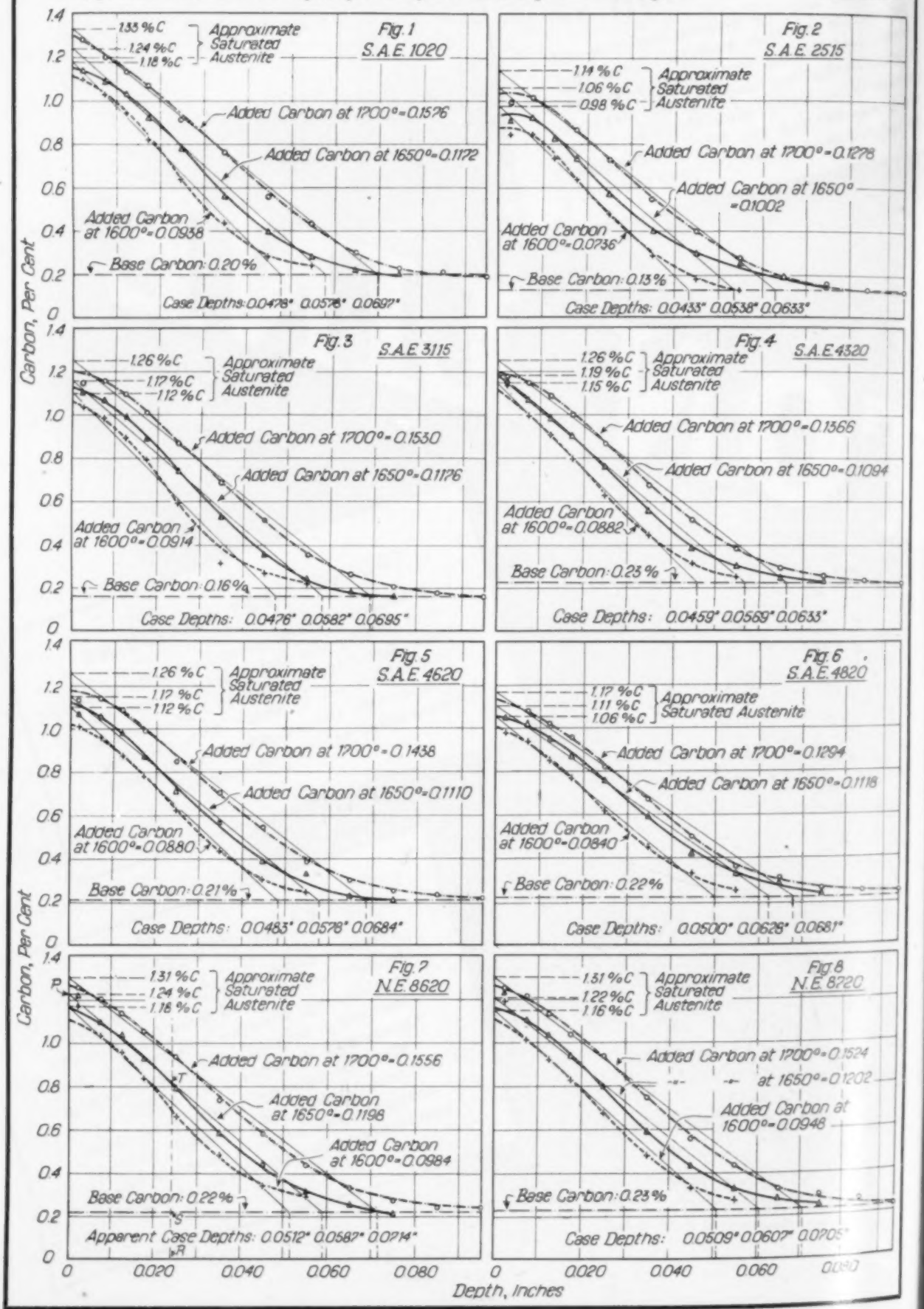
Plants also in Chicago, Detroit, San Francisco and Toronto, Canada

At the Metal Show: BOOTH C.130, Arena

Carbon-Penetration Curves

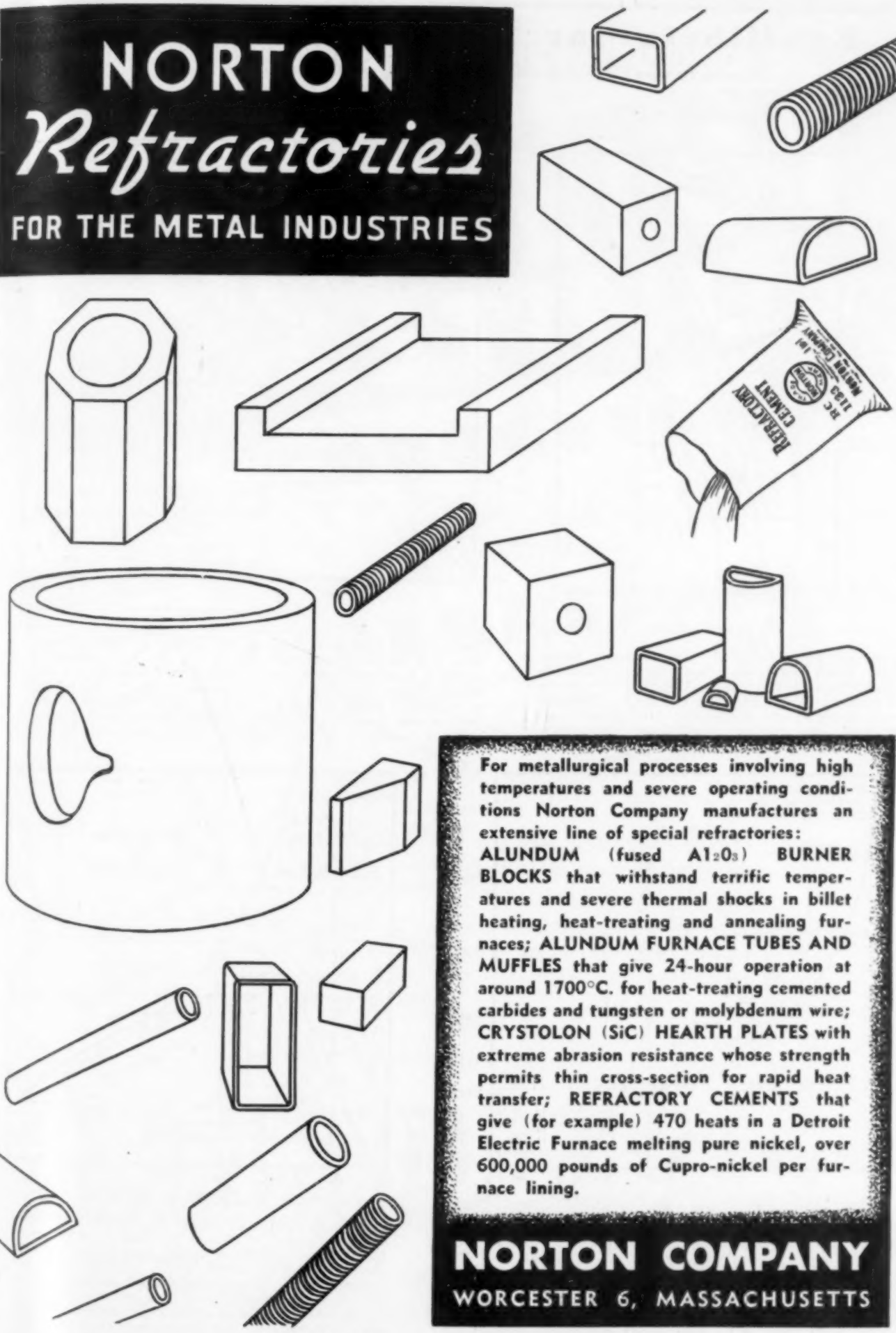
7½ hr. at heat, in mixture of 55 parts Drycolene and 8 parts natural gas

F. E. Harris



NORTON *Refractories*

FOR THE METAL INDUSTRIES



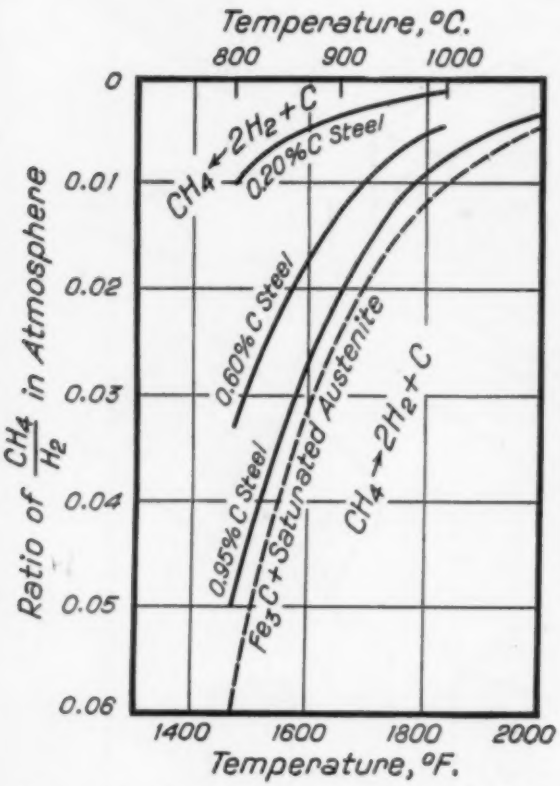
For metallurgical processes involving high temperatures and severe operating conditions Norton Company manufactures an extensive line of special refractories: ALUNDUM (fused Al_2O_3) BURNER BLOCKS that withstand terrific temperatures and severe thermal shocks in billet heating, heat-treating and annealing furnaces; ALUNDUM FURNACE TUBES AND MUFFLES that give 24-hour operation at around 1700°C. for heat-treating cemented carbides and tungsten or molybdenum wire; CRYSTOLON (SiC) HEARTH PLATES with extreme abrasion resistance whose strength permits thin cross-section for rapid heat transfer; REFRACTORY CEMENTS that give (for example) 470 heats in a Detroit Electric Furnace melting pure nickel, over 600,000 pounds of Cupro-nickel per furnace lining.

NORTON COMPANY

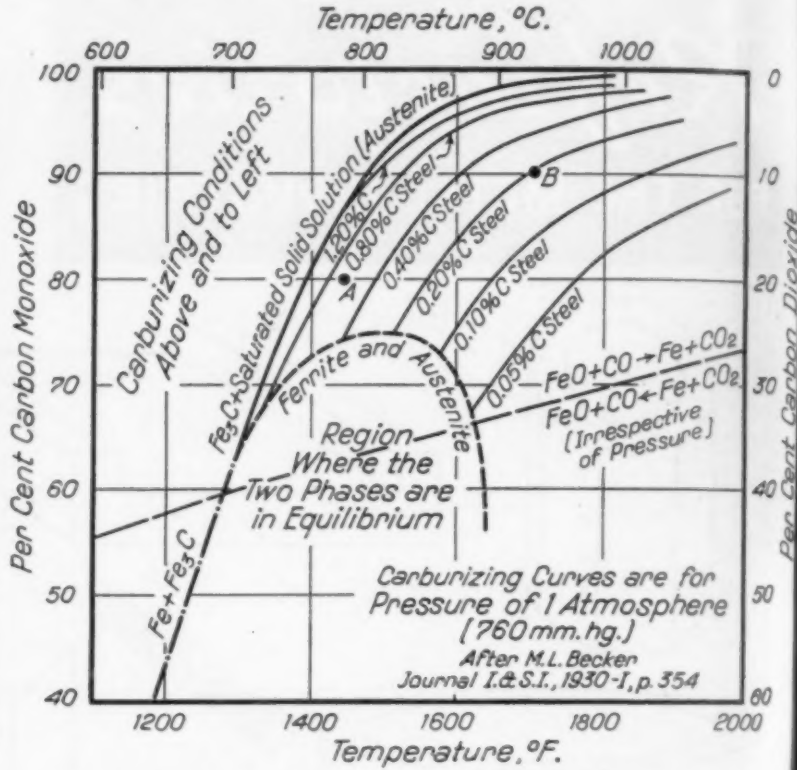
WORCESTER 6, MASSACHUSETTS

Equilibria for Gas-Steel Reactions

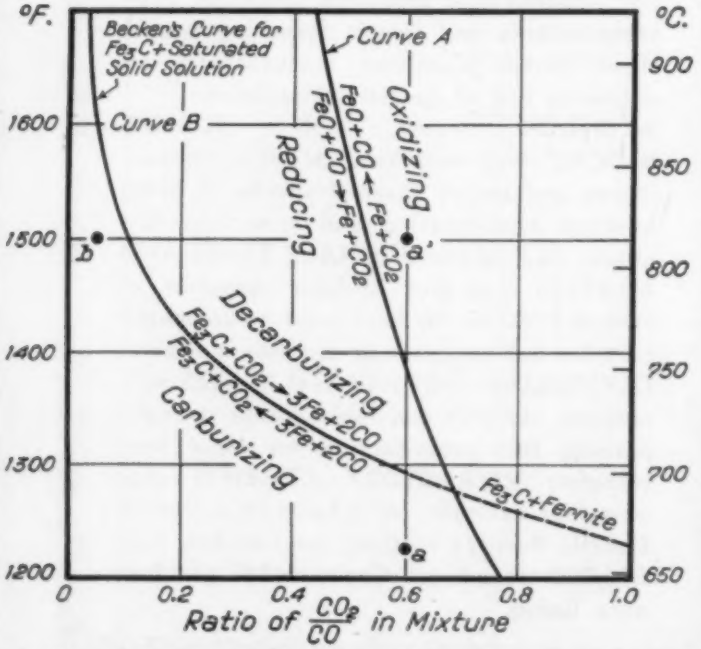
Relation Between Gas Composition, Temperature, and Carbon Content in Steel



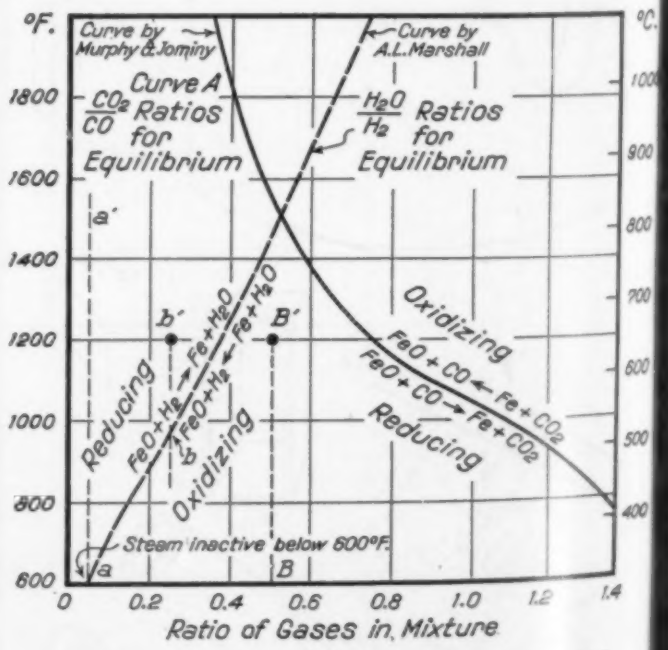
Above Curves, Adapted by Stansel From Sykes' Work, Indicate That Almost Pure H_2 Decarburizes Hot Steel (Conditions Above and Left of Corresponding Curves). Methane breaks down almost completely into carbon and hydrogen, carburizing steel (and depositing excess soot) at conditions below curves



Carburizing Reactions Depend on Carbon in Steel. Thus: 80% CO, 20% CO_2 at 1450° F., (point *A*) will carburize 0.40% C steel and lower, but decarburize 0.80% C steel and higher. However 90% CO, 10% CO_2 at 1700° F., (point *B*) is relatively inert to 0.20% C steels, will carburize lower carbon and decarburize higher carbon steels. Partial pressures, i.e., $CO + CO_2 < 100\%$, raise curves and shift to left



Action of Carbon Oxides Depends on Temperature. For instance, a dried atmosphere containing 6% CO_2 and 10% CO or ratio 0.6 (easily secured by partial combustion of fuel gas) would tend both to reduce and carburize at a 1225° F. anneal (Point *a*), but would both decarburize and oxidize at 1500° F. (Point *a'*). For "bright hardening" the CO_2 must be reduced well below Curve *B* (for instance, 1/10 the CO, as Point *b*, at 1500° F.). The above statements neglect the fact that the pressure of $CO + CO_2$ is less than 1 atmosphere



Oxidizing Action of Steam May Be Counteracted by 20 Times As Much Hydrogen (Line *a-a'*). Larger proportions of steam may scale the metal during cooling (line *b'-b*). Oxidizing — and decarburizing — propensities of moist gas may likewise be counteracted by carrying excess CO in the mixed carbon oxides present in the furnace atmosphere (for instance, CO_2 : CO = 0.5, or line *B-B'*, on the reducing side of curve *A*)

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Prepared Atmospheres

By C. E. Peck, Westinghouse Electric & Mfg. Co.

Composition and Cost of Typical Controlled Atmospheres

Mark	Description	Air-Gas Ratio	Approximate Composition						Dew Point	Gas for M Cu.Ft. Atmosphere	Cost per M Cu.Ft.	Nature of Atmosphere
			N_2	CO	CO_2	H_2	CH_4	O_2				
No. 1	Completely burned fuel	10:1 *(a)*	89.0	0.5	10.0	0.5	0.0	0.0	*(b)*	115 *(c)*	$0.08 *(d)*	Non-combustible; slightly reducing
No. 2	Partially cracked fuel (Self propelled)	6:1 *(a)*	69.0	10.0	5.0	15.0	1.0	0.0	*(b)*	145 *(c)*	$0.10 *(d)*	Combustible; toxic; medium reducing
No. 3	Completely reacted fuel (Auxiliary heat needed)	2.75:1 *(a)*	41.7	19.0	0.0	38.0	1.3	0.0	−10° F.	200 *(c)*	$0.18 to 0.25 *(e)*	Combustible; toxic; most reducing
No. 4	No. 1 scrubbed of CO_2 and H_2O	10:1 *(a)*	98.0	1.0	0.0	1.0	0.0	0.0	−50° F.	125 *(c)*	$0.20 to 0.40 *(e)*	Non-combustible; inert
No. 5	No. 2 scrubbed of CO_2 and H_2O	6:1 *(a)*	72.0	11.0	0.0	16.0	1.0	0.0	−50° F.	150 *(c)*	$0.22 to 0.42 *(e)*	Combustible; toxic; reducing
No. 6	Dissociated ammonia	No air	25.0	0.0	0.0	75.0	0.0	0.0	−60° F.	22.2 lb. NH_3	$2.00 to 4.00 *(f)*	Combustible; reducing
No. 7	No. 6 completely burned	1.88:1 *(g)*	99.0	0.0	0.0	1.0	0.0	0.0	*(b)*	13.7 lb. NH_3	$1.20 to 2.40 *(f)*	Non-combustible; inert
No. 8	No. 6 partially burned	1.25:1 *(g)*	80.0	0.0	0.0	20.0	0.0	0.0	*(b)*	14.9 lb. NH_3	$1.30 to 2.60 *(f)*	Combustible; slightly reducing

(a) Air-gas ratios are representative for natural gas containing practically nothing but methane. For high hydrogen city gas, ratios are about 50% of values given; for city gas with medium hydrogen and high CO, ratios are about 40% of values given. For propane, ratios are approximately twice the values given in the table, and for butane about three times.

(b) Dew points correspond to room temperatures unless auxiliary drying equipment is added. Dew point may be reduced to 40° F. by simple refrigeration equipment; to −50° F. or less by use of absorbent towers.

(c) Values are in cu.ft. for high methane natural gas. For various types of manufactured city gas, double the values given. For propane, requirements are half of values given, and for butane one third.

(d) Costs figured on raw natural gas at 50¢ per M cu.ft., electricity at 1¢ per kw-hr., water at 5¢ per M gal. Use of city gas usually doubles the cost figures given.

(e) Low value when reactivating moisture absorbent with steam; high value when using electrical heat.

(f) Costs based on 7¢ per lb. NH_3 in tank car lots and 16¢ per lb. for cylinder quantities. Electricity for dissociation at 1¢ per kw-hr.

(g) Dissociated ammonia.

Atmospheres Suitable for Heat Treatment of Different Metals

Material Processed	Process	Temperature Range, °F.	Time Cycle ("Long" if Over 2 Hr.)	Required Surface	Atmospheres Which Will Give Desired Results	Atmospheres Commonly Used
		Bright or Clean Annealing				
Low carbon steels	Anneal	1200 to 1350	Long	Bright	2, 4, 5, 6, 7, 8	2
Medium carbon steels	Anneal (no decarburization)	1200 to 1450	Long	Bright	4, 5, 6, 7, 8	4
High carbon steels	Anneal (no decarburization)	1200 to 1450	Long	Bright	4, 5, 6, 7, 8	4
Alloy steels, medium & high carbon	Anneal (no decarburization)	1300 to 1600	Long	Bright or clean	4, 5, 6, 7, 8	4, 5
High speed toolsteels including molybdenum high speeds	Anneal (no decarburization)	1400 to 1600	Long	Bright or clean	4, 5, 6, 7, 8	4
Stainless steels, chromium & nickel-chromium	Anneal	1800 to 2100	Short and long	Bright	6	6
High silicon steel, electrical sheet	Anneal	1900 to 2000	Long	Clean	4, 7	4, 7
Copper	Anneal	400 to 1200	Long or short	Bright	1	1
Various brasses	Anneal	800 to 1350	Long or short	Clean	1	1
Copper-nickel alloys	Anneal	800 to 1400	Long or short	Bright	4, 7	4
		Automatic Brazing or Soldering Operations				
Low carbon steels	Copper brazing	2050	Short	Bright	2, 3, 5, 6, 8	2
Medium & high carbon steels	Copper brazing (no decarburization)	2050	Short	Bright	3, 5, 6, 8	3
Alloy steels, medium & high carbon	Copper brazing (no decarburization)	2050	Short	Bright	3, 5, 6, 8	3
High carbon, high chromium steels	Copper brazing	2050	Short	Bright	6	6
Stainless steels	Copper brazing	2050	Short	Bright	6	6
Copper or brass	Phos-copper brazing or silver soldering	1500 to 1600	Short	Bright	1	1
		Bright Hardening and Tempering				
Medium carbon steels	Hardening	1400 to 1600	Short	Bright or clean	3, 4, 5, 6, 7, 8	3
High carbon steels	Hardening	1400 to 1800	Short	Bright or clean	3, 4, 5, 6, 7, 8	3
Alloy steels, medium & high carbon	Hardening	1400 to 1800	Short	Bright or clean	3, 4, 5, 6, 7, 8	3
High speed toolsteels, including molybdenum high speeds	Hardening	1800 to 2400	Short	Bright or clean	3, 4, 5, 6, 7, 8	3
All classes of ferrous metals	Tempering or drawing	400 to 1200	Short	Bright or clean	2, 4	2

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The A-B-C of Corrosion & Heat Resisting Steels

Arrangement due to F. R. Palmer. Adapted from The Book of Stainless Steels, Second Edition

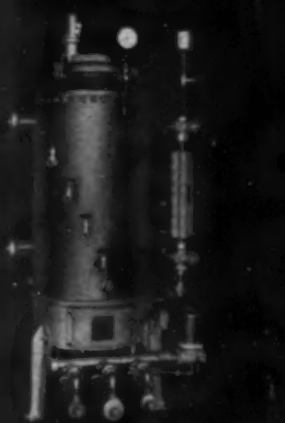
Group A (Martensitic)	Group B (Ferritic)	Group C (Austenitic)
Chemical Analysis Chromium less than about 16%; carbon in balance but ordinarily less than about 0.40%. May contain a little tungsten, nickel, silicon, columbium, aluminum, and more frequently molybdenum. Magnetic.	Chromium more than about 16%; carbon quite low, but can increase as chromium goes up. May contain small percentages of copper, nickel, silicon, molybdenum, tungsten, nitrogen. This group is magnetic.	Contains enough nickel to make steel austenitic and non-magnetic. They usually contain twice as much chromium as nickel or vice versa; total alloy content at least 24%. Carbon quite low. (Manganese sometimes substituted for nickel, in part.)
Heat Treatment Respond to hardening and tempering. Resulting physical properties depend on chemical analysis (principally carbon content).	Harden hardly at all. 18% Cr toughened by long anneal at more than 1400° F., and air cooling. Avoid decarburizing the skin. 25% chromium gets best strength and toughness by rapid cooling from 1650°.	Do not respond to hardening by heat treatment. Must be rapidly cooled from soaking heat at 1900 to 2150° F. to retain austenitic structure free of carbides. (Brinell 140 to 170).
Toughness Are structurally dependable after heat treatment; not brittle in notched sections or under impact. Suffer some loss in impact after tempering in 800 to 1100° F. range.	Laminated structure, from coarse ferrite in ingot, causes low impact values, but proper rolling and heating gives adequate toughness in rods, bars, and sheets. Structure is refined by alloying with nitrogen.	Extremely tough at all temperatures down to liquid air. Dependable against shock except when corroded at grain boundaries (a preventable condition).
Grain Growth and Structural Changes at High Temperatures Not subject to excessive grain growth. Thoroughly dependable for supporting any load or shock within their carrying capacity up to 1400° F. Brittleness in plain chromium steels when cooled after long heating is avoided by addition of molybdenum.	The chromium-irons low in carbon and those high in silicon or aluminum (when cold worked) are subject to excessive grain growth, especially above 1900° F. Grain growth reduced by nitrogen. Long service at temperatures up to 1600° F. makes them brittle when cold, although they are not brittle at working temperatures.	Alloys near the austenite-martensite border line tend to precipitate carbides at grain boundaries during service at 800 to 1600° F., losing some toughness and becoming susceptible to intergranular attack. This is controlled by very low carbon, by titanium or columbium, by increasing the chromium and nickel, or by prior "stabilization."
Strength at Elevated Temperatures Much better than straight carbon steel for temperatures up to 1000 or 1200° F. Retain tensile properties up to 750° F.	Heat resisting varieties quite tough at temperatures up to 1600° F. Inferior to Group C in creep resistance.	Have high creep strength up to 1200° F. which is enhanced by tungsten or molybdenum. Toughness impaired in non-stabilized alloys by service at 800 to 1600° F.
Hot Working Qualities Readily forged, pierced, or rolled at 2000 to 1700° F. Preheat and soak stock at 1600° F. Plain high chromium steels air harden on cooling.	May be forged, rolled, or pierced. Should be heated quickly. Forge from 2200° F. down to 1750° F. On last heat continue gingerly down to 1400° to refine grain; then anneal. Alloys do not air harden.	May be forged, rolled, or pierced. Preheat and soak at 1600° F., heat quickly to 2200° F., forge down to 1850° F. Hot short range: 1800 to 1300° F. Alloys do not air harden.
Cold Working Qualities Low carbon varieties can be easily cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn.	Can be cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn, especially when warm (300 to 500° F.).	Can be cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn. Work-harden twice as rapidly as Groups A and B.
Machinability Machine satisfactorily with properly designed tools when heat treated to 200 to 250 Brinell. Free-cutting grade contains complex sulphides or selenium.	Machine satisfactorily with properly designed tools. Cold working and high sulphur or selenium improve machinability.	Most difficult of all even with super high speed and carbon tools. Use sharp tools having greater top rake than usual, and cut continually. Free-cutting grade contains sulphur or selenium and phosphorus.
Riveting Make excellent cold rivets. Air hardening, high chromium steels not recommended for hot rivets driven above 1500° F.	Extra precautions required to avoid brittle rivets. Conical heads should be cold upset on ground bars; rivets driven at 1425° F. into chamfered holes.	Excellent for either hot or cold rivets. Hot rivets may be driven at a high temperature (1900° F.).
Welding Properties Preheated parts can be welded with gas, electric arc, or resistance. Anneal immediately before weld air hardens. Little grain growth. Columbium or aluminum increases ductility of welds.	Can be welded. Anneal to reduce embrittlement alongside weld. Those metals subject to grain growth are brittle adjacent to the weld. Those metals not subject to grain growth yield satisfactory welds.	Can be welded with gas, electric arc, or resistance. Weld does not air harden and is very tough. Only the very low carbon or alloys stabilized with Ti, Co or Mo should be welded if article must resist corroding media.
Corrosion Resistance Increases with chromium content; inferior to Groups B and C. Resists weather, water, steam, and mild corrodents when chromium is 11.5% or more. If carbon is relatively high, metal must be hardened and tempered (below 1000° F.).	Possess corrosion resisting properties superior to Group A; increases with chromium content. Especially good for nitric and other oxidizing acids.	Corrosion resistance depends largely upon total alloy content. Markedly improved by molybdenum. Resists nearly all corrodents measurably better than Groups A and B; especially good for organic acids. Severe pitting may occur in stagnant chloride solutions.
Scale Resistance Increases with chromium content. Generally useful for continuous temperatures up to 1200° F., and in some services up to 1500° F.	Superior to Group A, especially when chromium is above 25%; then resist reducing atmospheres up to 2100° F., resist oxidizing gases up to melting points, and sulphur gases up to 1800° F.	Excellent where combination of high temperature and corrosion is to be met. High chromium, low nickel alloys required to resist sulphurous gases. Addition of 2 to 3% silicon markedly improves scale resistance.

INDUSTRIAL GAS EQUIPMENT

McKee Mixers for single-valve control

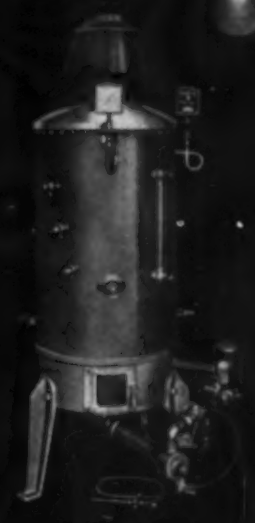
McKee Pressure Blowers 2 oz. to 2 lbs. pressure

McKee Box Burner for atmospheric firing

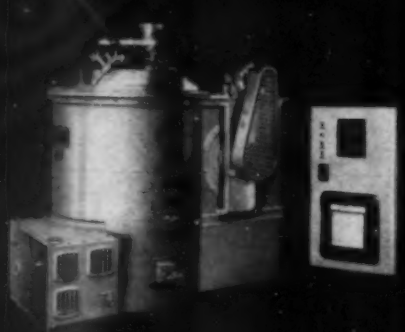


McKee Gas Fired Dowtherm Vaporizers

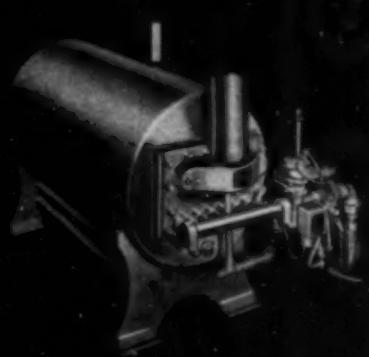
Eclipse Aluminum Melting Furnace



McKee Gas Fired Steam Boilers



Eclipse Rotair Air Draw Furnace



McKee Gas Immersion Water Heaters

Eclipse Gas Fired Forging Furnace

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ROCKFORD ILLINOIS

McKee Eclipse

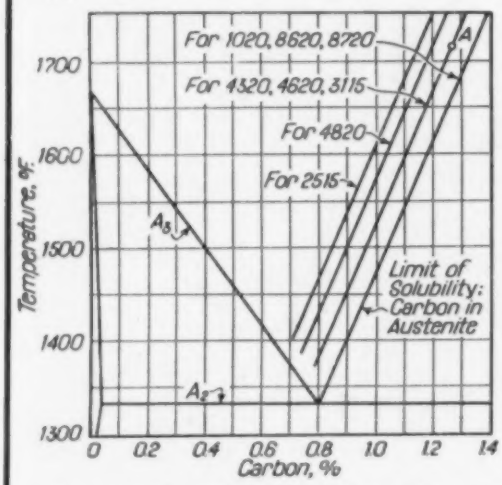
Carburizing and Diffusion Data

for eight common carburizing steels

By F. E. Harris

See *Metal Progress*, August, 1943, page 265

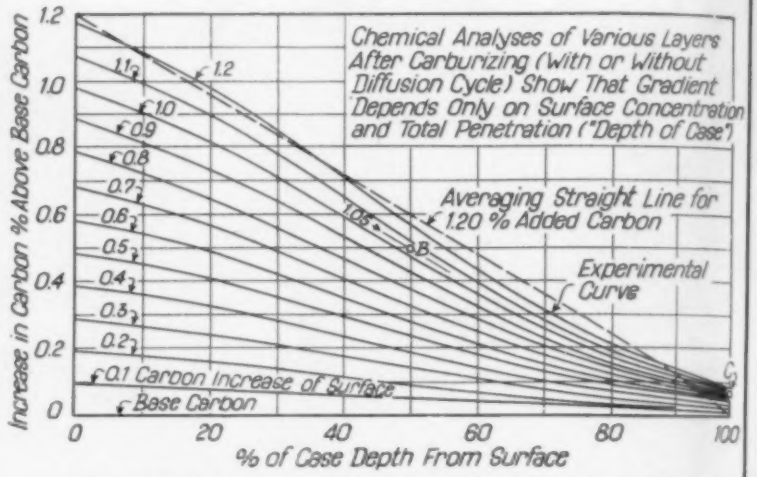
% C (Maximum Carbon) at Surface



For example: 4320 carburized at 1700° F., in an atmosphere that maintains saturated austenite at the surface, will have 1.25% max. surface carbon (Point A).

"% C Added" is 1.25 minus 0.20 = 1.05

Carbon Gradients



For example: % C added to the 4320 steel at half case depth is 0.50% (Point B); this is added to the carbon of the core ("base carbon"), so the actual analysis would be

0.50 + 0.20 = 0.70% carbon at half case depth

Area below experimental curve measures the carbon added to the entire case, and equals the area below the "averaging straight line". Intersection of latter with horizontal axis defines "case depth". Carbon analysis at this point in our example is

0.07 (Point C) + 0.20 (original carbon in steel) = 0.27%

Case Depths (C.D.) in Inches

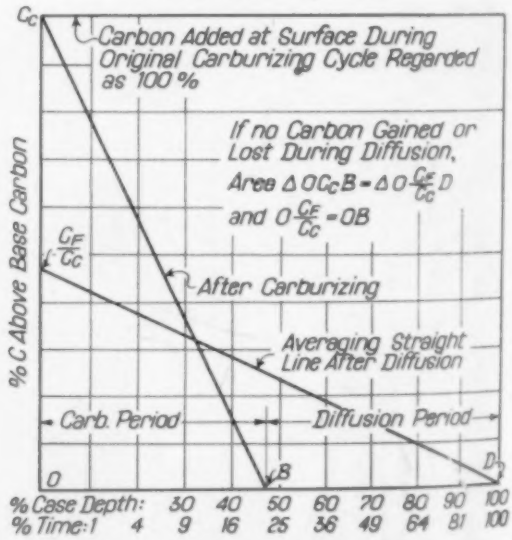
A function of temperature and time:

$$C.D. = K_{temp.} \sqrt{Time}$$

Time in Hr.	Temperature, °F.									
	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850
1	0.008	0.010	0.012	0.015	0.018	0.021	0.025	0.029	0.034	0.040
2	0.011	0.014	0.017	0.021	0.025	0.030	0.035	0.041	0.048	0.056
3	0.014	0.017	0.021	0.025	0.031	0.037	0.043	0.051	0.059	0.069
4	0.016	0.020	0.024	0.029	0.035	0.042	0.050	0.059	0.069	0.079
5	0.018	0.022	0.027	0.033	0.040	0.047	0.056	0.066	0.077	0.089
6	0.019	0.024	0.030	0.036	0.043	0.052	0.061	0.072	0.084	0.097
7	0.021	0.026	0.032	0.039	0.047	0.056	0.066	0.078	0.091	0.105
8	0.022	0.028	0.034	0.041	0.050	0.060	0.071	0.083	0.097	0.112
9	0.024	0.029	0.036	0.044	0.053	0.063	0.075	0.088	0.103	0.119
10	0.025	0.031	0.038	0.046	0.056	0.067	0.079	0.093	0.108	0.126
11	0.026	0.033	0.040	0.048	0.059	0.070	0.083	0.097	0.113	0.132
12	0.027	0.034	0.042	0.051	0.061	0.073	0.087	0.102	0.119	0.138
13	0.028	0.035	0.043	0.053	0.064	0.076	0.090	0.106	0.123	0.143
14	0.029	0.037	0.045	0.055	0.066	0.079	0.094	0.110	0.128	0.149
15	0.031	0.039	0.047	0.057	0.068	0.082	0.097	0.114	0.133	0.154
16	0.032	0.039	0.048	0.059	0.071	0.084	0.100	0.117	0.137	0.159
17	0.033	0.040	0.050	0.060	0.073	0.087	0.103	0.121	0.141	0.164
18	0.033	0.042	0.051	0.062	0.075	0.090	0.106	0.125	0.145	0.169
19	0.034	0.043	0.053	0.064	0.077	0.092	0.109	0.128	0.149	0.173
20	0.035	0.044	0.054	0.066	0.079	0.094	0.112	0.131	0.153	0.178
21	0.036	0.045	0.055	0.067	0.081	0.097	0.114	0.134	0.157	0.182
22	0.037	0.046	0.056	0.069	0.083	0.099	0.117	0.138	0.161	0.186
23	0.038	0.047	0.058	0.070	0.085	0.101	0.120	0.141	0.164	0.190
24	0.039	0.048	0.059	0.072	0.086	0.103	0.122	0.144	0.168	0.195
25	0.039	0.049	0.060	0.073	0.088	0.106	0.125	0.147	0.171	0.199
26	0.040	0.050	0.061	0.075	0.090	0.108	0.127	0.150	0.175	0.203
27	0.041	0.051	0.063	0.076	0.092	0.110	0.130	0.153	0.178	0.206
28	0.042	0.052	0.064	0.078	0.094	0.112	0.132	0.155	0.181	0.210
29	0.042	0.053	0.065	0.079	0.095	0.114	0.134	0.158	0.185	0.214
30	0.043	0.054	0.066	0.080	0.097	0.116	0.137	0.161	0.188	0.217

For example: 4320 carburized at 1700° F. for 11 hr. at temperature would attain "case depth" of 0.083 in. If 0.100 in. were specified it would require 16 hr.

Diffusion Cycles


C_C
Carbon Added at Surface During Original Carburizing Cycle Regarded as 100 %
If no Carbon Gained or Lost During Diffusion, Area $\Delta OC_CB = \Delta O\frac{C_F}{C_C}D$ and $O\frac{C_F}{C_C} = OB$
$\frac{C_F}{C_C}$
After Carburizing
Averaging Straight Line After Diffusion
Carb. Period
Diffusion Period
B
D_T
0
% C Above Base Carbon
% Case Depth: 30 40 50 60 70 80 90 100
% Time: 1 4 9 16 25 36 49 64 81 100

Example: Required carburizing and diffusion times at 1700° F. for 0.100-in. case in 4320, max. carbon at surface = 0.70% (approx. eutectoid)

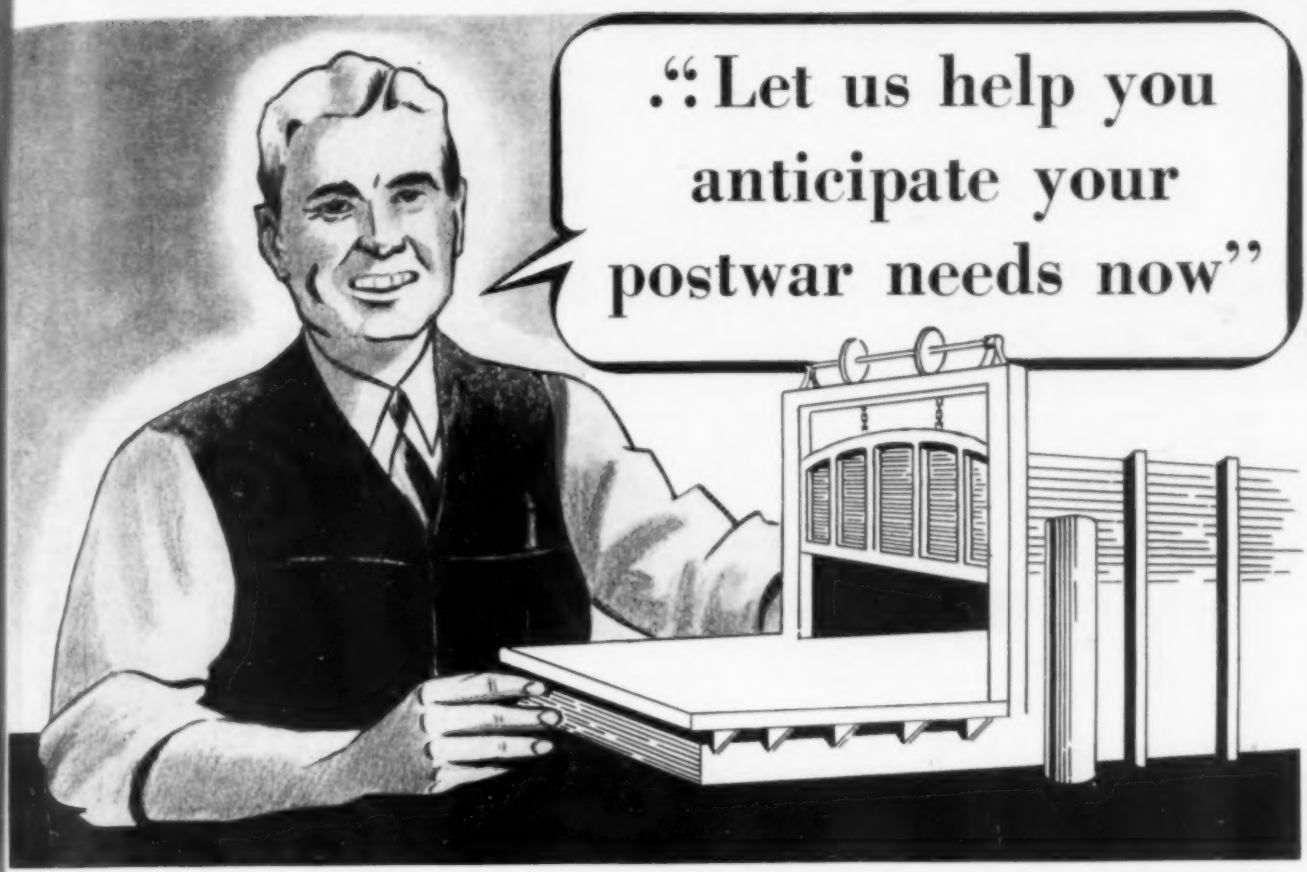
T = total time = 16 hr. (from table at left)

C_D = % C increase over base carbon after diffusion = 0.70% minus 0.20% = 0.50

C_C = % C increase over base carbon after carburizing = 1.25 minus 0.20 = 1.05

Carburizing time = $T \times \left(\frac{C_D}{C_C}\right)^2 = 16 \times \left(\frac{0.50}{1.05}\right)^2$ = 3 hr. 40 min.

Diffusion time = 16 minus 3.64 = 12 hr. 20 min.



☆ When conversion to peace-time operations becomes an actuality, new and complex problems are certain to arise. New products and processes will demand entirely new types of equipment. Redesign will, in some cases, be a satisfactory solution. In other cases furnaces and heat treating equipment will require complete rebuilding. Regardless of the problems that confront you, depend on Flinn & Dreffein to provide the answers. Our Engineers are specialists in the design, engineering and construction of better heat treating units for efficient, economical production. Call on us today for help on current and anticipated needs.

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WEAN ENGINEERING COMPANY, INC.
WARREN, OHIO

Properties of Refractory Materials, Except Fireclay

Compiled by Stuart M. Phelps, and Copyrighted 1935 by American Refractories Institute, Technical Dept., Mellon Institute.

Material (1)	Composition of the Pure Material		Melting Point	True Specific Gravity	Hardness (Moh's Scale)	Mean Specific Heat (17)	Thermal Expansion (Note 22)	Thermal Conductivity (2)		
	Formula	Composition %						At 1000°F.	At 1600°F.	At 2400°F.
Andalusite	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810°C. 3290°F.	3.20	7.5	0.168 (18)	6.2*			
Chromite	$FeO.Cr_2O_3$ (3)	Cr_2O_3 68 FeO 32	2180°C. 3956°F.	4.5	5.5	0.22*	8.0*	10.0*	10.9*	12.1*
Corundum	Al_2O_3	Al_2O_3 100	2050°C. 3722°F.	4.0 (24)	9	0.304*	8.5	23.0*	26.5*	30.0*
Cyanite (Kyanite)	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810°C. 3290°F.	3.6±	4 to 7		4.9* (4)			
Diasporite (Diaspore) (5)	$Al_2O_3.H_2O$	Al_2O_3 85.1 H_2O 14.9	2050°C. 3722°F.	3.4 to 3.5	6.5 to 7	(Note 6)	6.5*			
Dolomite	$CaCO_3.MgCO_3$	CaO 30.4 MgO 21.9 CO_2 47.7	(Note 23)	2.81 to 2.95	3.5 to 4.0	0.222 (19)	14.0			
Dumortierite	$8Al_2O_3.6SiO_2.$ $B_2O_3.H_2O$	SiO_2 64.6 Al_2O_3 28.5 B_2O_3 5.5 H_2O 1.4	1810°C. 3290°F.	3.30	7		5.2*			
Forsterite	2MgO.SiO_2	MgO 57.3 SiO_2 42.7	1910°C. 3470°F.	3.22	6 to 7	0.22 (19)	10.5*	11.1*	10.6*	10.3*
Graphite	C	C 100	>3000°C. >5432°F.	2.25	1 to 2	0.29	2.2			
Magnesia spinel	MgO.Al_2O_3	MgO 28.2 Al_2O_3 71.8	2135°C. 3875°F.	3.6	8	0.257	8.5	12.2*	13.3*	14.5*
Mullite	$3Al_2O_3.2SiO_2$	Al_2O_3 71.8 SiO_2 28.2	1810°C. 3290°F.	3.03		0.175 (20)	5.3 (7)			
Periclase (Magnesia) (8)	MgO	MgO 100	2800°C. 5072°F.	3.64 to 3.67	5.5 to 6.0	0.285	13.5*	19.5*	15.5*	13.0*
Quartz (9) (Quartzite)	SiO_2	Silica 100	1400°C. (10) 2552°F.	2.653	7	0.263*	32.6* (11) 4.6 (12)	8.8*	10.7*	13.3*
Silicon carbide	SiC	Si 70 C 30	2250°C. (13) 4082°F.	3.17 to 3.21	9 to 10	0.19 (14)	5.2 (15)	142*	110*	80*
Sillimanite	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810°C. 3290°F.	3.24	6.5 to 7.5	0.175				
Zircon (Zirconium silicate)	$ZrO_2.SiO_2$	ZrO_2 67.1 SiO_2 32.9	2550°C. 4622°F.	4.7	7.5	0.132 (21)	4.5			
Zirconia (Zirconium oxide)	ZrO_2	Zr 73.9 O 26.1	2700°C. 4892°F.	5.5 to 6.0	6.5	0.16	6.6 (16)	12.0*	13.0*	14.0*

*1. These properties refer to pure materials and not to commercial refractories which may differ because of impurities, bonding materials, and process of manufacture. The specific heat, thermal expansion and thermal conductivity data, however, may be used for engineering purposes and especially those marked with asterisk (*) which were obtained from commercial products.

2. Thermal conductivity in B.t.u. per in., per hr., per sq.ft., per °F., averaged from the more reliable data on refractories.

3. General chemical formula for chromite is $RO \cdot R_2O_3$. The RO oxide is usually FeO and may be replaced in part by MgO, while the R_2O_3 is mostly Cr_2O_3, but may be replaced in part by Al_2O_3 and Fe_2O_3.

4. Indian.

5. Commercial diaspore is composed of diasporite grains bonded with clay.

6. Probably close to 0.26.

7. Synthetic, pure.

8. Magnesite is amorphous, or crystalline like periclase, depending upon the heat treatment it has received.

9. Ganister is the commercial form for use in refractories, about 98% silica.

10. Crystobalite is the stable form of silica above 1470° C., and has the melting point of 1713° C. (3115° F.).

11. Value is for silica brick, mean expansion in range 20 to 300° C.

12. Value is for quartz, mean expansion in range 300 to 1135° C.

13. Dissociation temperature; oxidation may begin at 900° C. (1652° F.).

14. Varies with temperature.

15. This figure, and those for thermal conductivity, are for recrystallized material.

16. Pure material sintered.

17. For the range 20 to 1000° C. (68 to 1832° F.) unless noted.

18. For the range 0 to 100° C.

19. For the range 20 to 100° C.

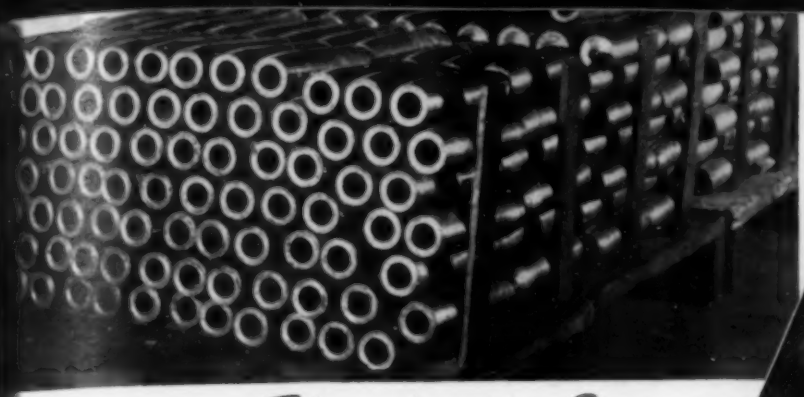
20. For the range 20 to 800° C.

21. For the range 21 to 51° C.

22. Values for the mean reversible thermal expansion per ° C. times 10^6, for the range 20 to 1000° C. unless noted.

23. Dissociates at very high temperatures.

24. Alpha modification.



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Tempering?

Carburizing?

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Massachusetts Steel Treating Corp.
118 HARDING ST. - WORCESTER 3-7972

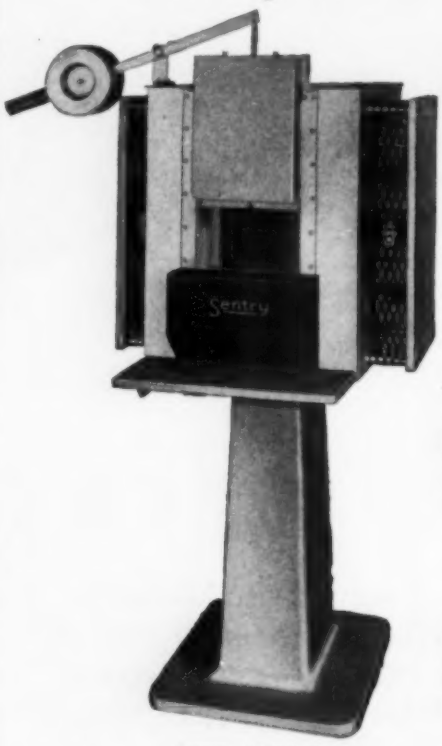
WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Conductivity and heat transfer charts. Johns-Manville. Bulletin 167.

Insulating firebrick. Babcock & Wilcox Co. Bulletin 162.

See for Yourself!



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Electric-furnace graphite mold and sintering boats and carbon he treating boxes are described in Ca log Section M-8000. National Carb Co. Bulletin 545.

"Carbofrax" refractory skid rail are described and blueprinted fo many types of furnaces in th 20-page booklet by the Carborundu Co. Bulletin 500.

Wesgo super refractory shapes a described in this bulletin. Wi ability to withstand almost an amount of thermal abuse, the shapes possess high fusing range (u to 3100 deg. F.), low thermal co ductivity and complete freedo from impurities such as iron. Wes ern Gold and Platinum Works. Bu letin 526.

Zircon refractories in aluminu open hearth furnaces. Chas. Tayl Sons Co. Bulletin 347.

Steel Plant Cement for hot or co patching of soaking pits, op hearths, electric furnaces, forgi furnaces and reheating furnaces described in new folder by Elect Refractories & Alloys Corp. Bulleti 407.

Heavy Duty Refractories. Norto Co. Bulletin 164.

D-E insulating materials and the application are described in ne data booklet by Armstrong Cork C Bulletin 208.

FINISHING • PLATING • CLEANING

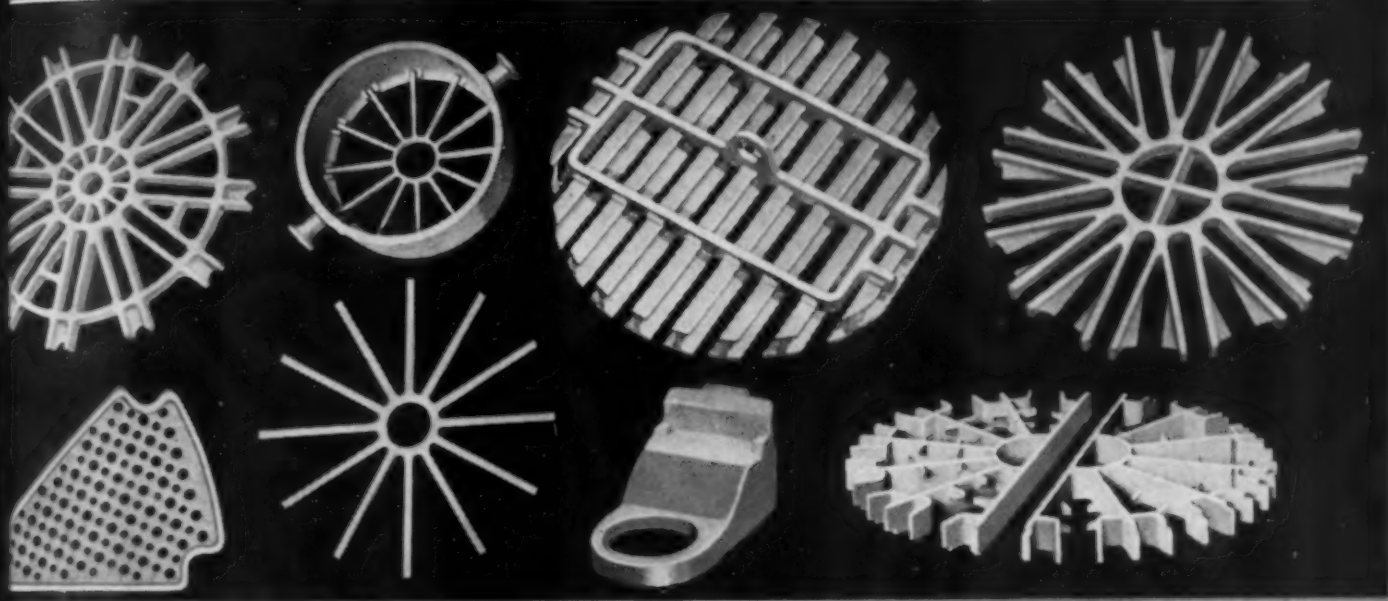
Revised editions of two bulleti —No. 8, Anodizing and No. 9, Ca mium Plating — have been issued Kelite Products, Inc. Each one ou lines the practice and technique the operations involved. Bullet 589.

A protective, deep black finish steel. Heatbath Corp. Bulletin 17

Cyanide zinc and bright zinc pla ing with Turco Type X, Turco Por kleen and Turco Penetrol is describ in this 10-page booklet by Tur Products, Inc. Bulletin 495.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.
Other Manufacturers' Literature Lists on Pages 652, 654, 656, 658, 660, 662, 6 666, 668, 670, 672, 674, 676, 680, 681, 6 896, 897, 898, 972, 988, 989 and 991.

How Our "Jig-Saw Puzzle" Experts Solve Pit Furnace Loading Problems



Ingenious Driver-Harris designs ncrease loading capacities 50% to 100%

"Show us how to increase our workpiece charges in our pit furnaces" famous aircraft engine maker asked. In 9 days our engineers had the nswer. A variety of spiders, collars, screens and spacers were created nd assembled in jig-saw fashion to pack 85 camshafts into a 20 inch ircle, increasing output 50%.

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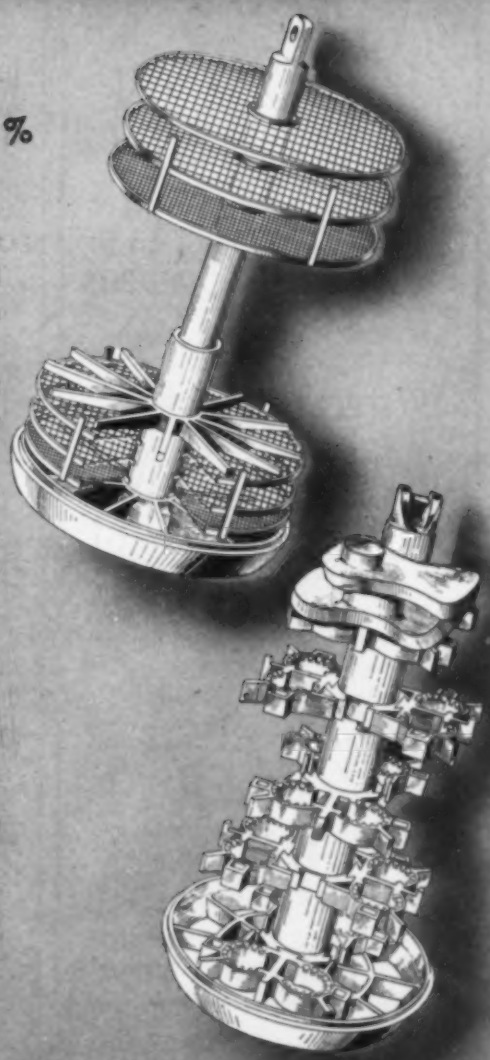

All fixtures illustrated above were designed and produced by Driver-Harris engineers to expand pit furnace capacity and flexibility for a leading aircraft engine manufacturer.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Helpful chart classifies Cowles metal cleaners for improved cleaning operations. Cowles Detergent Co. Bulletin 594.

Roto-Finish equipment for deburring, buffing, polishing and coloring. Sturgis Products Co. Bulletin 170.

"Deoxidine" for a better rust removing and metal cleaning job is described along with several applications in this 4-page leaflet. American Chemical Paint Co. Bulletin 528.

Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin 173.

New 144-page catalog "Chemicals by Glyco" features many tables of useful chemical and physical data. Glyco Products Co., Inc. Bulletin 449.

Three new booklets have been issued by the Enthone Co. describing an acid addition agent, hard drying rust-inhibiting waxes and a new alkali steel cleaner. Bulletin 420.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin 172.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin 212.

Airless Rotoblast. Pangborn Corp. Bulletin 176.

Rust inhibiting wax coatings for protection of metal. S. C. Johnson & Son, Inc. Bulletin 180.

Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin 179.

Cadmium Plating. E. I. duPont deNemours & Co., Inc. Bulletin 177.

Use Handy Coupon on Page 652
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Other Manufacturers' Literature Listed on Pages 652, 654, 656, 658, 660, 662, 664, 666, 668, 670, 672, 674, 676, 680, 681, 688, 892, 897, 898, 972, 988, 989 and 993.

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WHAT'S NEW

MANUFACTURERS' LITERATURE

Several practical data sheets show ning methods used on aluminum, s and steel. Diversey Corp. tin 446.

"Surface-Peening" by shot-blasting to improve the strength of metal parts is described in this leaflet by W. W. Sly Mfg. Co. Bulletin 521.

T THE METALS SHOW...BOOTH E613

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Lead plating is discussed in new booklet issued by Harshaw Chemical Co. Bulletin 109.

Service report describes use of Oakite machining, drawing, degreasing and descaling materials. Oakite Products, Inc. Bulletin 210.

Catalog on finishing and cleaning. Frederick Gumm Chemical Co., Inc. Bulletin 292.

Jetal process and its characteristics as a protective coating. Alrose Chemical Co. Bulletin 213.

"Indium and Indium Plating". Indium Corp. of America. Bulletin 182.

Special data sheets on compounds for various cleaning jobs are offered by MacDermid, Inc. Bulletin 436.

Two informative cleaning booklets have been issued by Detrex Corporation. 16-page booklet emphasizes fundamental practices for economical use of degreasing solvents in metal cleaning departments. 8-page booklet describes alkali and emulsion cleaning compounds for all types of metal cleaning jobs. Bulletin 554.

ENGINEERING • APPLICATIONS • PARTS

A complete 168-page commercial catalog on powder metallurgy has been released by Chrysler Corporation's Amplex Division. It presents a wide variety of up-to-the-minute engineering developments and facts on powder metal bearings and parts. Bulletin 583.

Heat resisting alloys, cast-rolled-fabricated, and a line of heat treating equipment, are described and illustrated in this 12-page booklet. Michigan Steel Casting Co. Bulletin 584.

4-page bulletin describes and illustrates the various types of Meehanite manufactured for wear resisting applications. Meehanite Research Institute. Bulletin 585.

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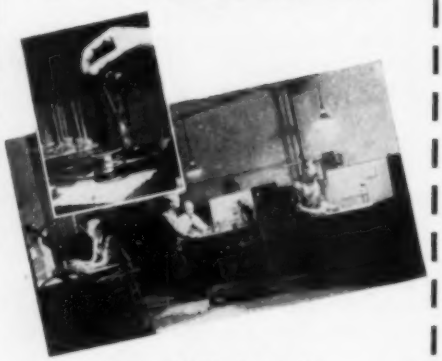

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Illustrated literature describes details and advantages of Elastic Stop Nuts. Elastic Stop Nut Corp. Bulletin 595.

Weldco crates and baskets that provide extra pay load, longer service life and greater safety are described in literature by the Youngstown Welding and Engineering Co. Bulletin 598.

Heat treating fixtures for pit-type furnaces are shown in new booklet by Driver-Harris Co. Bulletin 363.

Pressed steel pots are described by Bell & Gossett Co. in new Bulletin 364.

Specifications and physical properties of bronze and aluminum alloys are shown in Olds Alloys Co. Bulletin 457.

24-page catalog is guide to properties and use of Monsanto plastics. Monsanto Chemical Co. Bulletin 319.

Carburizing Boxes. Pressed Steel Co. Bulletin 193.

Chace manganese alloy No. 772 in sheets, strips, rod and special shapes described by W. M. Chace Co. Bulletin 190.

Catalog gives complete specification data on Bunting bearings and bars. Bunting Brass & Bronze Co. Bulletin 343.

16-page booklet gives engineering standards and technical information on "AERO-THREAD" screw thread system. Well-illustrated and helpful booklet by Aircraft Screw Products Co., Inc. Bulletin 567.

Illustrated leaflet presents data and uses of special alloys resisting corrosion, high temperatures and abrasion. The Duraloy Co. Bulletin 390.

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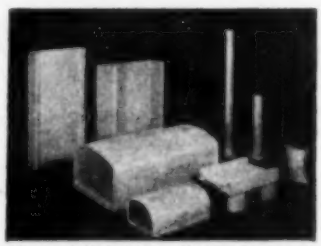

Typical "Carbofrax" shapes used in heat-treating furnaces.

Important, too, is the outstanding resistance of "Carbofrax" to mechanical abrasion, spalling and cracking. For these are the properties that ensure a long, trouble-free life and eliminate the need for frequent replacements.

The successful performance of "Carbofrax" hearths in this type of operation—where a great variety of work is handled—may help you assay their value for your own heat-treating furnaces. *Better still,* let us send a refractories engineer who will be glad to provide full details and make specific recommendations on how to secure results like these in your own plant. *Write today.*

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Refractories Division **Perth Amboy, N. J.**

District Sales Branches: Chicago, Philadelphia, Detroit, Cleveland, Boston, Pittsburgh.

Distributors: McConnell Sales & Engineering Corp., Birmingham, Ala.; Christy Firebrick Company, St. Louis, Mo.; Harrison & Company, Salt Lake City, Utah; Pacific Abrasive Supply Company, Los Angeles & San Francisco, California; Denver Fire Clay Company, El Paso, Texas; Smith-Sharpe Company, Minneapolis, Minn.

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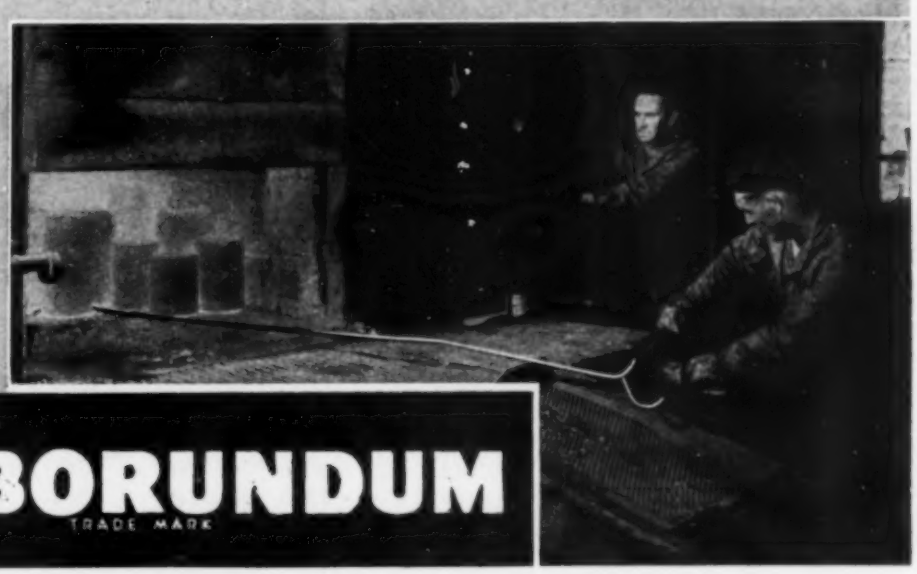


A close-up of one of the furnaces used for heavy work. Note the heavy loads placed on the "Carbofrax" hearth.

by CARBORUNDUM
TRADE MARK

Approximate Critical Temperatures

by M. J. R. Morris, R. Sergeson and G. W. Gable

In most instances found by examining microstructure of quenched ⅝-in. discs of 1-in. round, taken from furnace at 20° F. increments. Grain size of steel unknown. Rate of heating and cooling about same as in furnace-cooling for commercial annealing

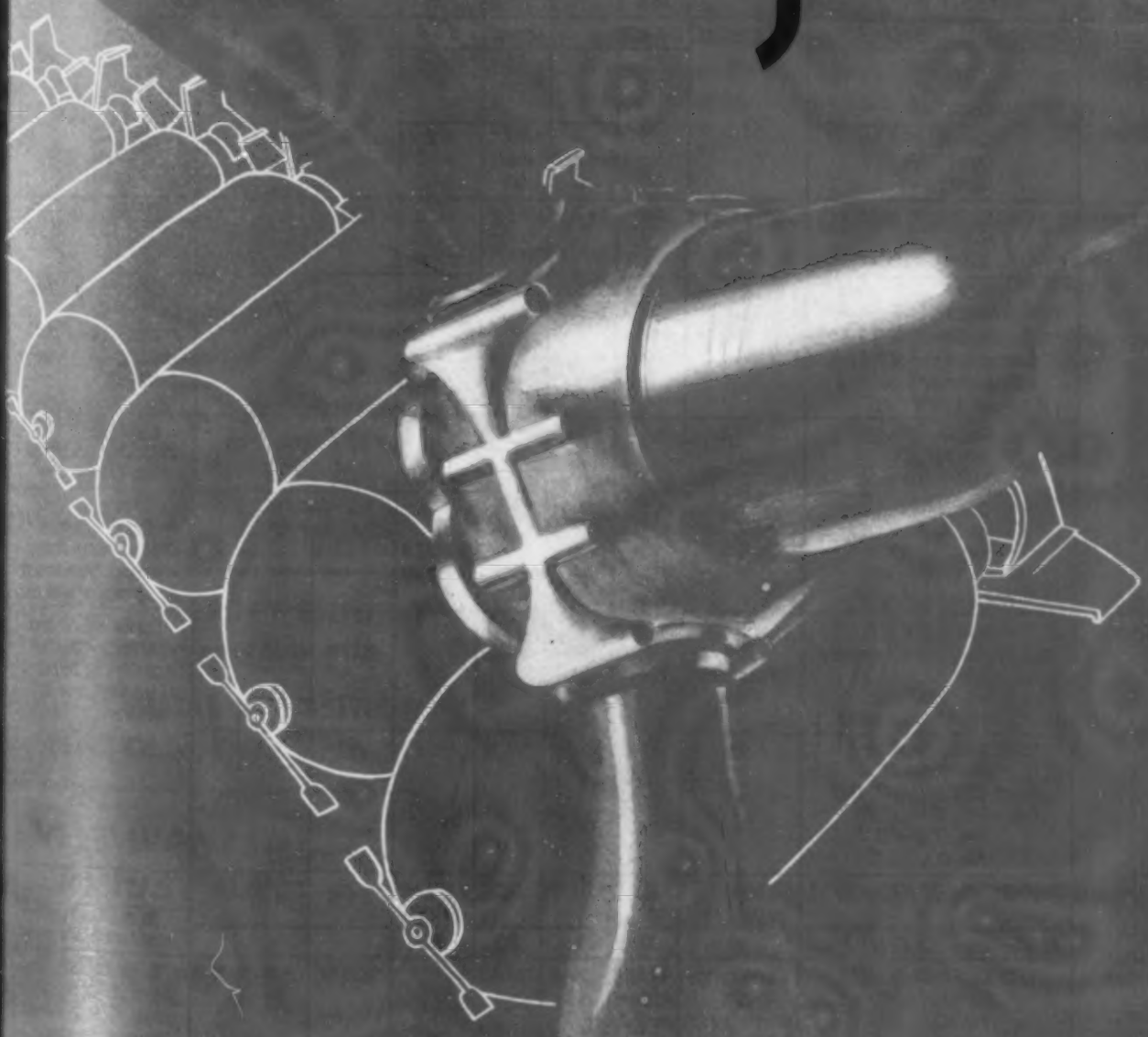
Number	On Slow Heating			On Slow Cooling		
	Ac_1	Ac_2	Ac_3	Ar_3	Ar_2	Ar_1
Carbon Steels						
1010	1350	1405	1605	1570	1400	1255
1015	1355	1410	1585	1545	1395	1265
1020	1355	1410	1570	1535	1395	1260
1025	1355	1405	1545	1515	1405	1255
1030	1350	1405	1495	1465	1405	1250
1035	1345		1475	1455	1395	1275
1040	1340		1455	1415		1275
X1040 (a)	1340		1450	1340		1270
1045	1340		1450	1405		1275
X1045 (a)	1335		1420	1330		1270
1050	1340		1425	1390		1275
X1050 (a)	1335		1400	1330		1270
1055	1340		1425	1390		1275
X1055 (a)	1335		1400	1330		1270
1060	1340		1410	1370		1275
1065 (a)	1340		1385	1345		1285
X1065	1335		1380	1330		1280
1070	1345		1370	1340		1280
1075 (a)	1350		1365	1340		1280
1080			1360	1285		
1095			1360	1290		
10150 (a)			1355	1290		
Free Cutting Steels						
1112	1355	1410	1590	1545	1395	1265
1120 (a)	1355	1405	1550	1510	1400	1255
X1315 (a)	1345	1420	1520	1495	1370	1245
X1330	1320	1400	1490	1380	1360	1240
X1335	1315	1390	1420	1360	1340	1220
X1340	1310		1400	1340		1210
Manganese Steels						
1330	1325		1480	1340		1160
1335	1315		1460	1340		1165
1340	1315		1435	1310		1160
1345 (a)	1315		1410	1300		1160
1350 (a)	1310		1400	1255		1105
1360 (a)	1305		1405	1200		1095
Nickel Steels						
2015 (a)	1375	1475	1575	1450	1400	1215
2115 (a)	1345	1455	1525	1475	1380	1195
2317	1300	1350	1440	1350	1260	1100
2320 (a)	1285	1345	1420	1235	1160	920
2330	1275	1315	1400	1180		1050
2335 (a)	1275		1375	1180		1050
2340	1280		1360	1180		1060
2345	1280		1350	1180		1060
2350 (a)	1280		1340	1180		1070
2515	1250	1335	1420	1220	1140	825
2520 (a)	1240	1340	1390	1175	1025	825
Nickel-Chromium Steels						
3115	1355	1400	1500	1470	1380	1240
3120	1350	1400	1480	1455	1380	1230
3125 (a)	1350	1395	1465	1400	1380	1220
3130	1345	1380	1460	1360		1220
3135	1340		1445	1300		1220
3140	1355		1415	1295		1220
X3140	1350		1430	1300		1240
3145	1355		1395	1295		1220
3150	1355		1380	1275		1215
3215 (a)	1350	1410	1465	1415	1350	1240
3220(a)	1350	1415	1460	1405	1355	1240
3230 (a)	1340		1435	1395		1240
3240	1335		1425	1280		1240
3245 (a)	1345		1400	1270		1225
3250 (a)	1340		1375	1255		1200
3312	1330	1370	1435	1240		1160
3325 (a)	1335	1365	1400	1230		1160
3330 (a)	1320	1360	1380	1225		1145
3335 (a)	1310		1360	1200		1100
3340 (a)	1290		1380	1180		1100
3415 (a)	1330	1370	1425	1340	1300	1220
3435 (a)	1290		1380	1200		1150
3450 (a)	1290		1360	1200		1100
Molybdenum Steels						
4023	1360		1540	1430		1240
4027	1360		1500	1400		1230
4032	1350		1495	1390		1225
4037	1320		1410	1340		1210
4042	1315		1405	1330		1205
4047	1310		1400	1320		1200
4063	1360		1390	1220		1190
4130	1395	1435	1485	1405	1395	1280
X4130	1395	1435	1480	1405		1250
4135 (a)	1395	1440	1475	1380	1360	1280
4140	1380		1460	1370		1280
4150	1365		1395	1355		1280
4340	1350		1425			725
4345 (a)	1345		1415	1200		725
4615	1335	1400	1485	1400	1320	1200
4620	1335		1470	1390		1175
4640	1320		1430	1300		1125
4650 (a)	1315		1410	1260		1125
4815	1300		1440	1310		800
4820	1300		1440	1260		760
Chromium Steels						
5120	1410*	1460*	1540*	1470*	1420*	1295*
5140	1370		1440	1345		1280
5150	1330*		1420*	1280*		1220*
52100	1340		1415	1315		1280
Chromium-Vanadium Steels						
6115 (a)	1420	1460	1550	1450	1380	1300
6120 (a)	1410*	1460*	1545*	1440*	1380*	1300*
6125 (a)	1400	1440*	1490*	1390*	1360*	1295*
6130 (a)	1390	1440	1485	1370	1340	1285
6135 (a)	1390*		1480*	1370*		1280*
6140 (a)	1390		1455	1375		1295
6145 (a)	1390		1450	1375		1290
6150	1385		1450	1375		1270
6195 (a)	1370		1425	1360		1300
Tungsten Steels						
7260 (a)	1360		1430	1370		1310
National Emergency Steels						
NE8620	1340*		1530*	1415*		1270*
NE8630	1350*		1480*	1340*		1210*
NE8637 (b)	1350*		1450*	1300*		1180*
NE8650 (b)	1340*		1420*	1240*		1210*
NE9255	1400		1500	1380		1320
NE9260	1400		1500	1380		1315
NE9420	1340		1510	1390		1270
NE9430	1360		1430	1240		1190
NE9440	1350		1425	1290		1190
NE9540	1360		1450	1320		1200
NE9542	1360		1450	1320		1200

*These determinations were obtained on a Leeds & Northrup transformation apparatus, or a Rockwell dilatometer.

(a) This number not in the official S.A.E. list for 1942.

(b) Molybdenum on high side of specification.

cleaning & finishing



annual reference issue

october 1944

Compiled by F.R. Morral

ELECTROPLATING METALS

Metals	Plating Solution: Grams per Liter	Anodes	Current Density: Amp/Sq.dm.	Voltage: Volts	Temp.,°C.	pH	Current Efficiency: %	Thickness Coating	Uses	Ref.
Brass	CuCN 26.2 $Zn(CN)_2$ 11.3 NaCn 45.0	75% Cu 25% Zn	1.0		27-35	10.3 to 11.0	75	0.5-5.0 μ	Rubber bonding	1
	CuCN 27.0 $Zn(CN)_2$ 9.0 NaCN 55.25 Na_2CO_3 30.0 NH_3 1.2	80% Cu 20% Zn	0.3 to 0.5	2-3	24-38				Difficult to plate directly on malleable cast iron and stainless steel	
	CuCN 18.0 $Zn(CN)_2$ 10.15 NaCN 12.0		0.4		26					
Cadmium	CdO (a) 23-39, (b) 20-32 NaCN 86-131, 66-110 Addition Agent	Soluble - Cd Insol. - Steel	0.5 to 5.4		20-35		85-98	*N.S. 0.0125mm. O.S. 0.0075+ T.S. 0.0038+	Finish coating by bright dip	2
Chromium	Cr_2O_3 400 SO_4 4	Insol. - Pb	4-10				10-15	0.00015 to 0.00050 mm.	Decorative	
	CrO_3 250 (SO_4) 2.5		5.7-15.5		40			0.025 mm./hr at 55°C. and 31 amp/sq.dm.	Hard plate at least 25.4 μ thick	3
Cobalt	$Co(NH_4)_2(SO_4)_2.6H_2O$ 175	Cast & rolled Cobalt	0.4-4.2		Room	5.5+	90-98			
	$CoSO_4$ 278 NaCl 17 H_3BO_3 45		3.8-17.5		Room	5	100			4
	$CoSO_4$ 278 NaF 14 H_3BO_3 45		3-5		R.T. and up	5.2	83-93			
Copper	$CuSO_4.5H_2O$ 180 H_2SO_4 45 Glue 0.003	Cast or rolled Cu	3-6		21-50		100		Electrotyping	5
	CuCN 120 NaCN 135 { NaOH 30 or KOH 42 } Brightener 15 Anti-pit agent 1.5	Electrolytic Cu	1.2-11	(a) 1-2 (b) 3-4	75-85		100	0.051 mm.	Bright deposits up to this thickness mostly used for plating. High speed bath	6
	CuCN 15 NaCN 23 Na_2CO_3 variable	Cast Cu or Electrolytic Cu				variable		0.0127 to 0.0254 mm.	Used for strike cleaning and some plating	7
	CuCN 26 NaCN 35 Na_2CO_3 30 Rochelle Salt 45 $(KNaC_4H_4O_6.4H_2O)$		7.5		50-80	12.2-12.8 (av. 12.6)	60-30% at 55°C. 20-40% at 70°C.		Striking, plating more easily controlled, heavy deposits. Base coating on steel to be coated with Ni or Cr	7
Gold	Metallic Au 2.1 (as fulminate or cyanide) KCN 15.0 Na_2HPO_4 4.0 Na_2CO_3 variable	Insoluble; or Soluble Gold	0.11 to 0.54	2-5	40-80		100%	0.0003 mm.	Cu, Brass, Ni and Ag readily plated. Steel must be plated first with one of the above	8
	"Salt water process" Metallic Au 1.2 $Na_4Fe(CN)_6.10H_2O$ 15.0 $Na_2HPO_4.12H_2O$ 7.5 Na_2CO_3 4.0 Na_2SO_3 0.15	Zn	0.54	2-3						
Iron	$FeCl_2.4H_2O$ 400-500	High purity Fe	6.5		90	0.01 N HCl				9
	$FeSO_4.(NH_4)_2SO_4.6H_2O$ 350	-"-	7.0		60	6.0			To built up undersized machine parts	
Lead (Lead continued on sheet 2)	$2(PbCO_3).Pb(OH)_2$ 150 50% HF 240 H_3BO_3 106 Glue 0.2	Corroding or chemical Pb	0.54 to 5.4 (av. 2.2)		25-40		100%	up to 0.025 mm.	Gives satisfactory plate directly on steel. Fine grained dense deposits	10

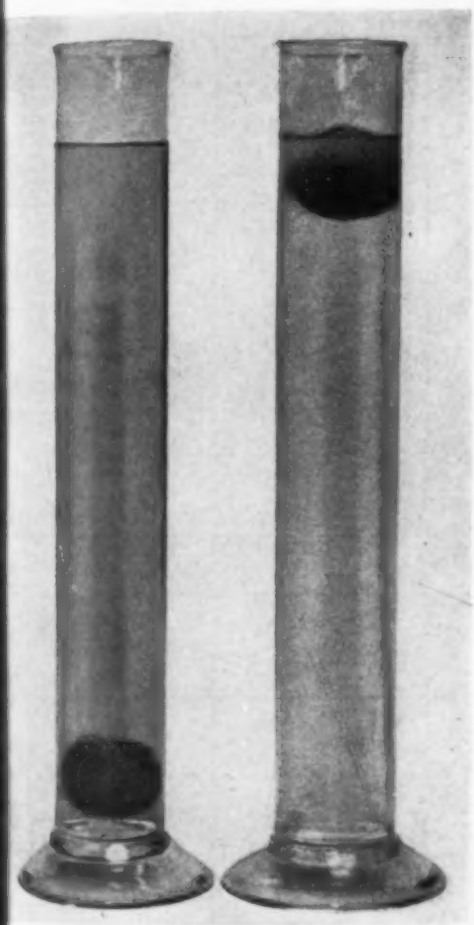
Modern Electroplating: paper-(1) p. 88; (2) p. 103; (3) p. 120; (4) p. 148; (5) p. 158; (6) p. 174; (7) p. 188; (8) p. 200; (9) p. 215; (10) p. 224.

Note: (a) barrel plating
(b) still -"-

* Minimum thickness of the three types specified in A.S.T.M. specification A165-40T

REMOVE SCALE AFTER HEAT TREAT

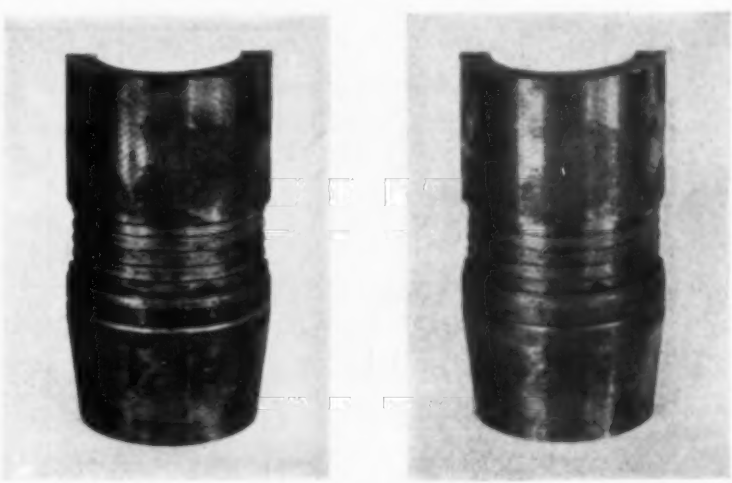
WITH DIVERSEY EVERITE



Diversey Everite is a powerful solvent specially developed to remove heat scale quickly and completely without harming the sound metal. Will not change dimensions of forgings and castings. Also removes rust from metal surfaces. Reduces hydrogen embrittlement. Economical . . . works only on oxide and other unwanted deposits . . . not on the metal. Easy to use by soak or circulating method. P.S.—Remove quenching oil with Diversey DC-22 in tank cleaning or DC-14 in power washer.

1. REDUCES HYDROGEN EMBRITTLEMENT

Here's proof—Place a small wad of steel wool in graduates filled with Diversey Everite and raw acid. Note how the steel wool is carried to the surface by bubbles of hydrogen released by the raw acid. In the Everite solution, the steel wool remains at the bottom . . . there's no evolution of hydrogen, no corrosion.



2. WILL NOT INJURE METAL SURFACE

Here's proof—Select two rusty pieces of steel. Place one in a solution of Diversey Everite and the other in raw acid. Note how Everite removes the rust quickly and completely, AND THEN STOPS while the raw acid continues to dissolve the sound metal after the rust is gone.

For Liberal Experimental Sample Write Metal Industries Dept.

THE DIVERSEY CORPORATION 53 W. Jackson Blvd. Chicago 4, Ill.

VISIT THE DIVERSEY EXHIBIT
SPACE #A-624
NATIONAL METAL EXPOSITION
Cleveland, Ohio, October 16-20

. . HELP WANTED?
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DIVERSEY D-MAN

Compiled by F.R. Morral

ELECTROPLATING METALS

Metals	Plating Solution: Grams per Liter	Anodes	Current Density; Amp/Sq.dm.	Voltage; Volts	Temp, °C	pH	Current Efficiency; %	Thickness Coating	Uses	Ref.
Lead (continued)	$2(PbCO_3)Pb(OH)_2$ 300 50% HF 480 H_3BO_3 212 Glue 0.2		0.54-7.6 (av. 3.2)				100%	up to 127mm	Barrel or still plating	10
	Pb 75 Total fluosilicate 150 Glue 0.2		0.54 to 8.8	0.1 to 0.2	35-40		100%		Cheap for large scale operations. Decomposes easily	
	Sulfamate Pb process Sp. gr. soln. 30°Be		0.5 to 4.5	(a) 3-8 (b) 9-14	25-50	1.3-2.0 (av. 1.5)	100%		Lubricant in wire drawing.	11
Nickel	$NiSO_4.7H_2O$ 240 $NiCl_2.6H_2O$ 45 H_3BO_3 30 Anti-pitting agent	97% Ni, rolled depolarized	4.3		43	1.5-3.0 4.5-5.6	90-100		Bright Ni deposits; grain size less than 0.0001 mm.	12 26
Platinum	NH_4NO_3 100 $NaNO_2$ 10 $Pt(NH_3)_2(NO_2)_2$ 16.5 NH_4OH (28%) 50	Pt	0.44	2.4		6.4-7			Use nickel undercoat	13
Palladium	$PdCl_2.2H_2O$ 3.7 Na_2HPO_4 100 $(NH_4)_2HPO_4.12H_2O$ 20 $C_7H_6O_2$ 2.5	Pt or Pd	0.2-0.3	1-2	50	7			Plate directly, or over flash Ni undercoat	14
Rhodium	H_2SO_4 (conc. C.P.) 20 Cc. Rh. metal preparation (Concentrated Solution) 2 H_3PO_4 (ortho) 85% 40 Cc. Rh. prepared 2.0	Insol. Pt	1-11		40-50				Use bright Ni undercoat	15
Ruthenium	$RuNOCl_3$ 4 H_2SO_4 conc. C.P. 20 Cc.		2.2	2.5						16
Silver	Ag metal 25-33 KCN (free) 30-45 K_2CO_3 30-90 CS_2 up to 0.0009	Ag 999.5 fine	0.5-1.5		24-32 (av. 27)	11.5-12	100%			17 27
* Tin	$SnSO_4$ 30-90 H_2SO_4 30-150 Addition agents (various) 0.5-350	Pure Sn	1.1-4.3 (also up to 43)	0.6-1.6	21-27		95-100			18
	$Na_2SnO_3.3H_2O$ (a) 90 (b) 150 NaOH 25 18.8 Na Acetate 15 22.5 H_2O_2 (100 vol.) 0.5 0.5	Pure Sn	1.08-4.32	4-6	60-80		60-90		19μ satisfactory for steel; 2.6-12.7μ for non-ferrous metals.	19
Zinc	$ZnSO_4.7H_2O$ 240-550 NH_4Cl 15-30 Addition Agent: $Al_2(SO_4)_3.18H_2O$ or $AlCl_3.6H_2O$ or $NaC_2H_3O_2.3H_2O$	98.5-99.9% Zn	1-3 (also up to 200)	4	24-30	3.5-4.5	99	0.0038 to 0.025mm.		20
	$Zn(CN)_2$ (a) 60 (b) 90 NaCN 23 37.5 NaOH 53 90	99.75% Zn	(a) 1-2 (b) 6-12		(a) 40-50 (b) 40-70		(a) 90-95 (b) 85-95			21
	$Zn(CN)_2$ (a) 37.5 (b) 60 NaCN 22.5 30 NaOH 30.0 45 Hg Salt 0.25 0.25	98.25% Zn + 0.5-1% Hg	1.1 to 1.6 (anode) up to 43 (cathode)	4-6	40 (30-50)		90			22
	$Zn(CN)_2$ (a) 60-82 (b) 60-82 NaCN 18.7-64 34-75 NaOH 75-112 75-97 Addition Agent	99.8%; Zn + other Zn-Al-Hg; Zn-Mg	0.2 to 10.7	(a) 1.5-6 (b) 10-15	20-45 prefer 22.8-32.8		75-95		Bright plate	23
Indium	For details see reference									24

(11) Am. Electroplating Society, June 1942; Modern Electroplating: (12) p. 239; (13) p. 278; (14) p. 279; (15) p. 281; (16) p. 283; (17) p. 293; (18) p. 320; (19) p. 333; (20) p. 346; (21) p. 365; (22) p. 366; (23) p. 369; (24) Steel, November 9, p. 80 (1942); (25) J.L. Bray and F.R. Morral, Surface Treatment of Metals.-A.S.M. 1941, p. 108; (26) W.S. Loose, Nickel Plating Magnesium Alloys. Trans. Electrochem. Soc. 81, (1942), Prepr. 6; (27) F.J. Bowen and L.I. Gilbertson. The Electrodeposition of Silver on Magnesium, Trans. Electrochem. Soc. 83, (1943), Prepr.

Note: In all electroplating of metals a standard procedure has to be followed. This consists of 4 fundamental steps. (25): (1) Preparation of the surface to be coated. (2) Activation of this surface. (3) Actual coating. (4) Finish of the coating. The details vary for the various metals. Some electrodeposits do not adhere directly to the basic metal and undercoats of metals adherent both to the basic metal and the coating have to be used. Certain metals offer difficulties in preparation. Magnesium is a good example. Special techniques using special electrolytic solutions have been developed (26, 27).

* Note: Fusion of tin on electrotinned strip by induction heating has been developed to close pinholes. G.E. Stoltz; Blast Furnace & Steel Plant 30, p. 1357 (1942).

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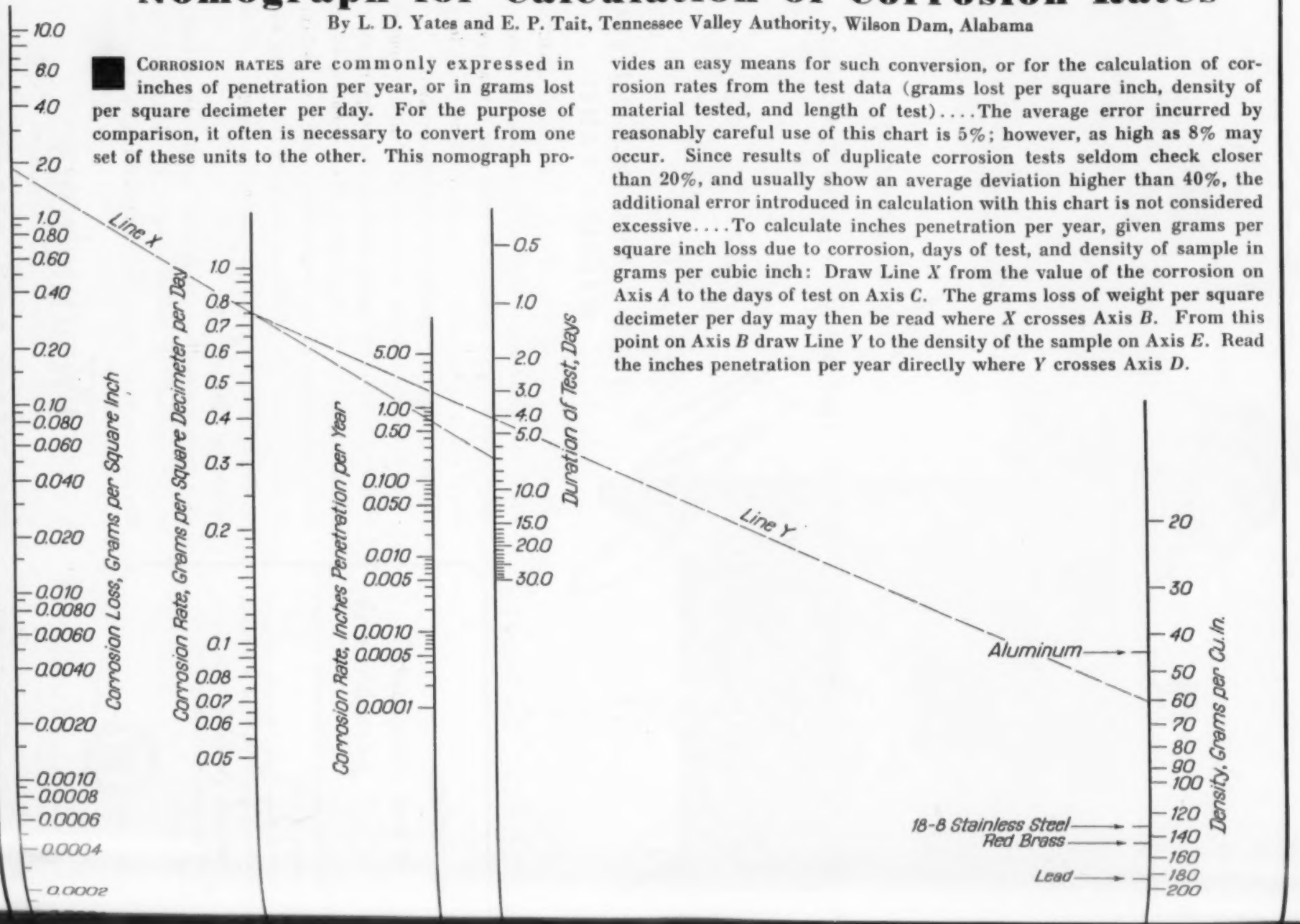
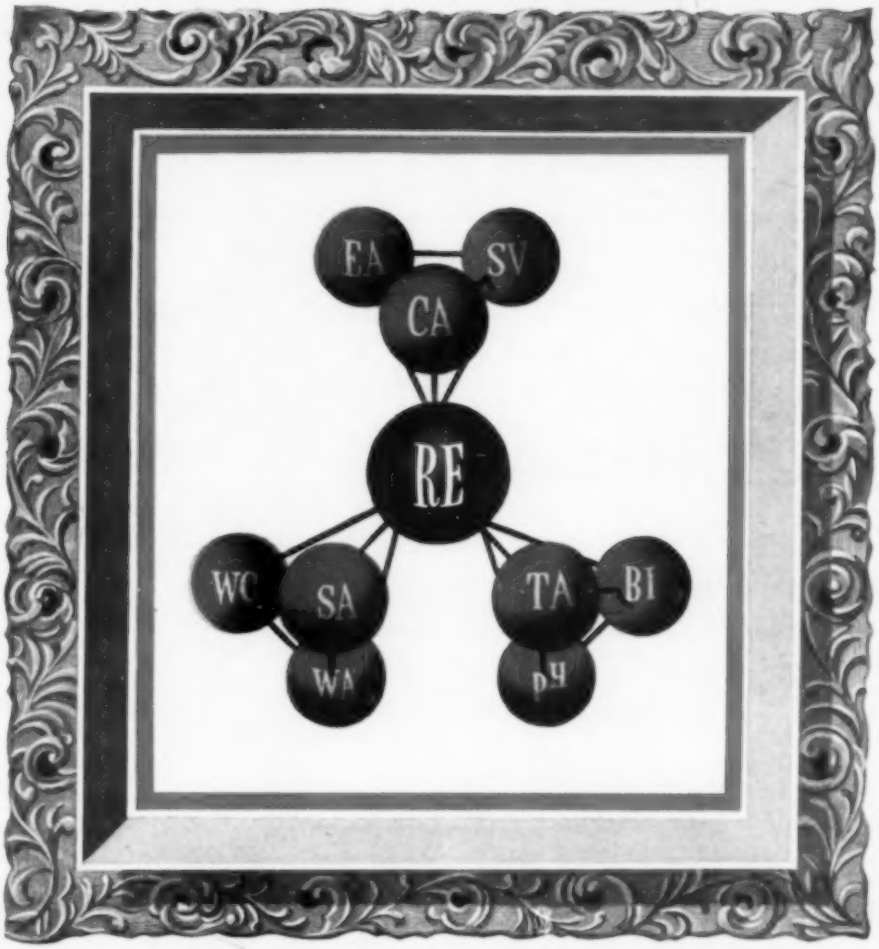
Nomograph for Calculation of Corrosion Rates

By L. D. Yates and E. P. Tait, Tennessee Valley Authority, Wilson Dam, Alabama

CORROSION RATES are commonly expressed in inches of penetration per year, or in grams lost per square decimeter per day. For the purpose of comparison, it often is necessary to convert from one set of these units to the other. This nomograph provides an easy means for such conversion, or for the calculation of corrosion rates from the test data (grams lost per square inch, density of material tested, and length of test)....The average error incurred by reasonably careful use of this chart is 5%; however, as high as 8% may occur. Since results of duplicate corrosion tests seldom check closer than 20%, and usually show an average deviation higher than 40%, the additional error introduced in calculation with this chart is not considered excessive....To calculate inches penetration per year, given grams per square inch loss due to corrosion, days of test, and density of sample in grams per cubic inch: Draw Line *X* from the value of the corrosion on Axis *A* to the days of test on Axis *C*. The grams loss of weight per square decimeter per day may then be read where *X* crosses Axis *B*. From this point on Axis *B* draw Line *Y* to the density of the sample on Axis *E*. Read the inches penetration per year directly where *Y* crosses Axis *D*.





PORTRAIT OF STEEL BEING PICKLED

Whether you are cleaning steel for electroplating, protecting metals against rust and corrosion, or preparing aluminum for spot-welding, this is the picture of working factors in the scientifically balanced chemical compound. It is a cement floor being cleaned. It is a diesel engine or coils being descaled. *It is Turco in action.*

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* *For a fuller explanation of these vital factors, write for Turco's "The Chemistry of Chemical Compounds," on your letterhead, please.*

- EA —*Emulsifying Action disperses grease and oil as tiny globules, suspends them, and prevents redeposition.*
- CA —*Colloidal Activity disperses solids into minute particles easily removed.*
- SV —*Saponifying Value is the ability to convert organic fats and oils into soluble soaps.*
- TA —*Total Alkalinity (or acidity) is the total amount of either available for cleaning.*
- BI —*Buffer Index is the ability to absorb either alkaline or acid soil to prolong solution efficiency.*
- pH —*A yardstick for measuring the energy of alkalinity or acidity.*
- SA —*Solvent Action is the ability to put soil into solution.*
- WA —*Wetting Action lowers surface and interfacial tensions, causing solution penetration to base surface.*
- WC —*Water Conditioning removes or controls the elements which cause water hardness.*
- RE —all the elements above are mobilized through Turco's Research and Experience.*

TURCO

INDUSTRIAL CHEMICAL COMPOUNDS

Write Dept. MP-10

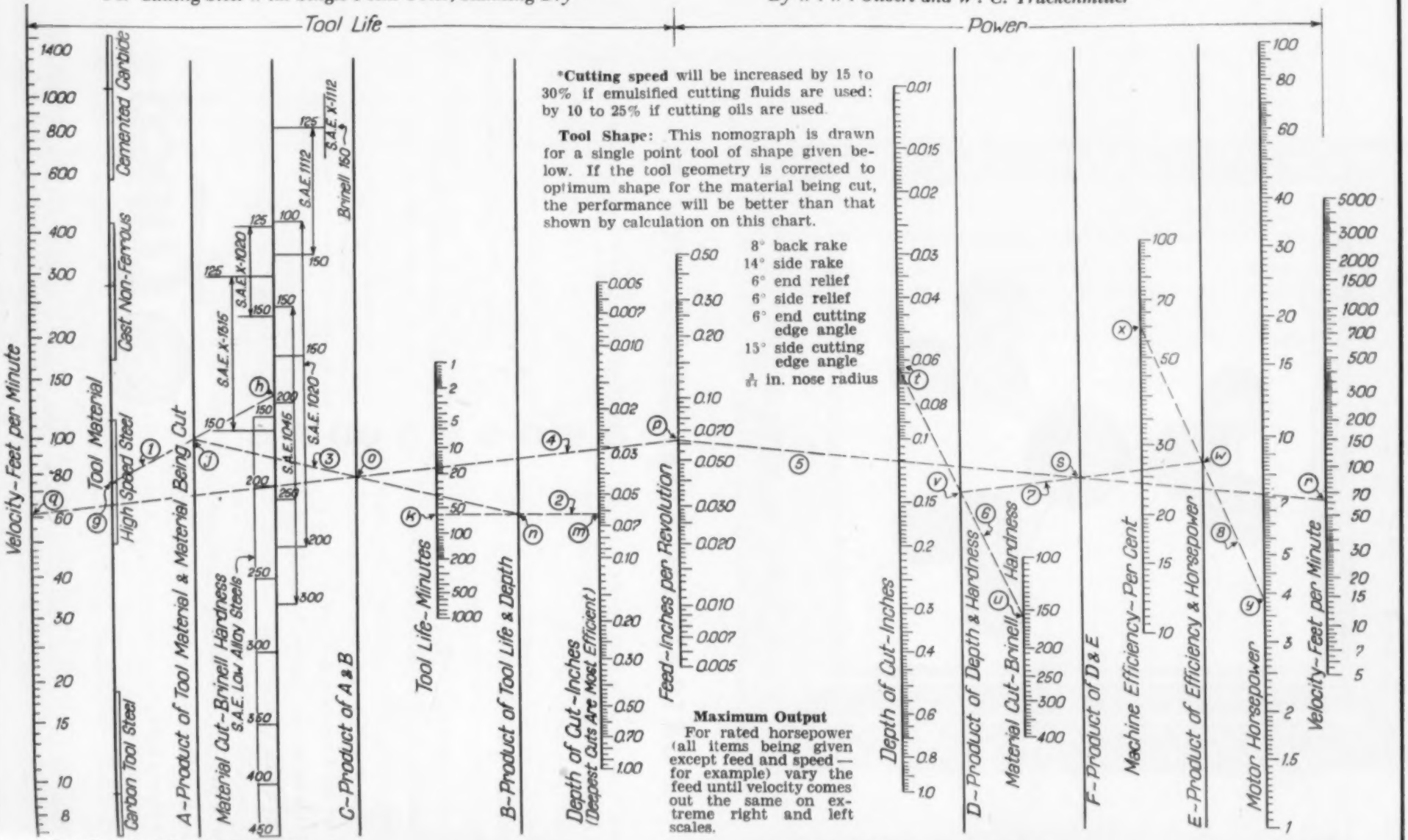
TURCO PRODUCTS, INC. *Main Office and Factory:* 6135 S. Central Avenue, Los Angeles 1 • *Southern Factory:* 1606 Henderson Street, Houston 10, Texas • *Chicago Office and Factory:* 125 West 46th Street, Chicago 9, Illinois • *Offices and Warehouses in All Principal Cities*

Metal Cutting Nomograph

Courtesy, American Society of Mechanical Engineers

*For Cutting Steel With Single Point Tools, Running Dry**

By W. W. Gilbert and W. C. Truckenmiller



***Cutting speed** will be increased by 15 to 30% if emulsified cutting fluids are used: by 10 to 25% if cutting oils are used.

Tool Shape: This nomograph is drawn for a single point tool of shape given below. If the tool geometry is corrected to optimum shape for the material being cut, the performance will be better than that shown by calculation on this chart.

- 8° back rake
- 14° side rake
- 6° end relief
- 6° side relief
- 6° end cutting edge angle
- 15° side cutting edge angle
- 1/64 in. nose radius

Maximum Output

For rated horsepower (all items being given except feed and speed — for example) vary the feed until velocity comes out the same on extreme right and left scales.

Sample Calculation for Tool Life:

Given—Tool material: high speed (Point g) } Draw Line 1,
Material cut: S.A.E. 1020, 160 hard (Point h) } Establish Point j
Desired tool life: 60 min. (Point k) } Draw Line 2,
Depth of cut: 0.0625 in. (Point m) } Establish Point n
Draw Line 3, between j and n, establishing Point o
Feed: 0.0625 in. per revolution (Point p)

Sample Calculation for Power Required:

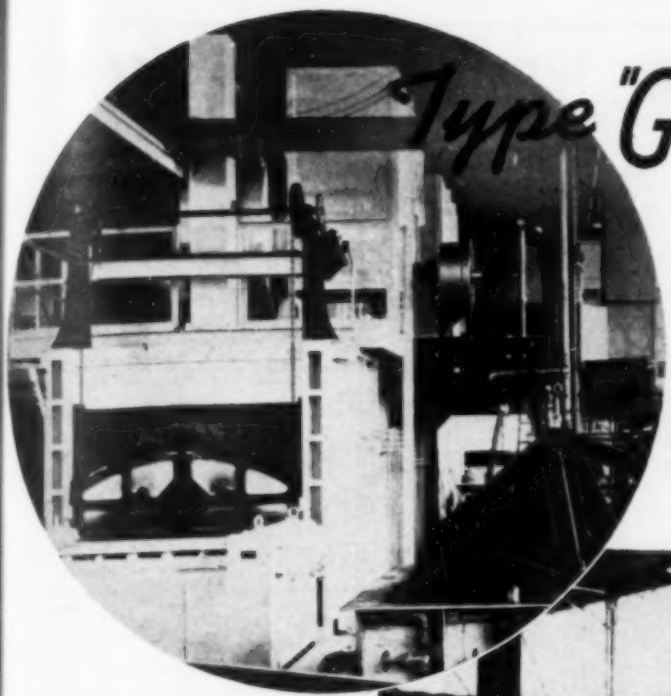
Given—Feed: 0.0625 in. per revolution (Point p) } Draw Line 5
Velocity: 60.5 ft. per min. (Point r) } Establish Point s
Depth of cut: 0.0625 in. (Point t) } Draw Line 6
Hardness of steel: 160 Brinell (Point u) } Establish Point v
Draw Line 7 between Points v and s, establishing Point w
Machine efficiency: 60% (Point x)

Metal Progress, April 1944, Page 686-B

Type "G" MOTOR BLOWERS

with

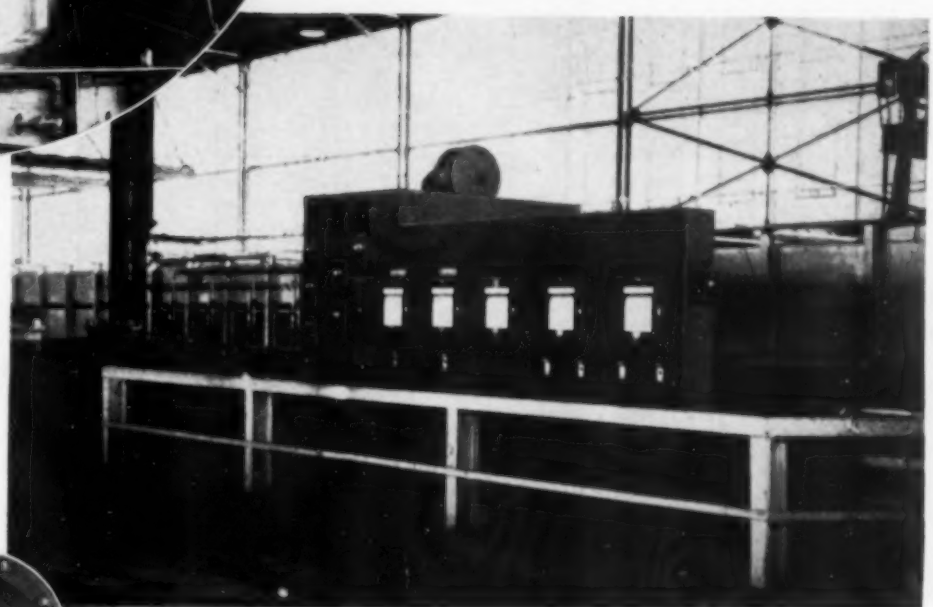
HAGAN FURNACES

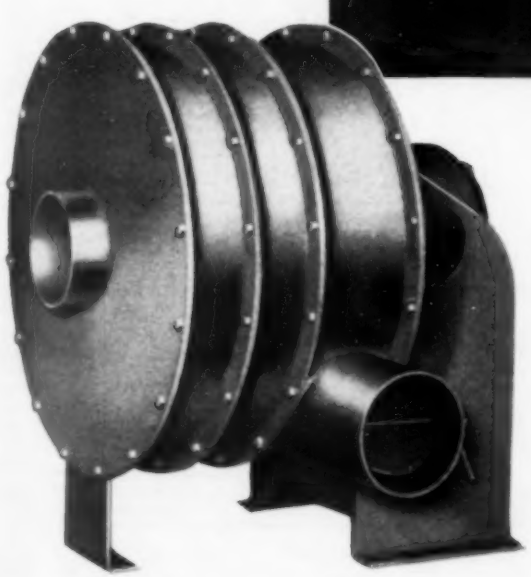


"Production line" handling of treated parts is possible with the convenient placing of furnaces, quench tanks and conveyors. The blower, mounted on a platform, takes no floor space.

•

Mounted atop and approximately in the center of this long car-type furnace is a Type "G" Motorblower supplying combustion air.





Designed for quick, easy installation, Type "G" Motorblowers require no special foundation.

This George J. Hagan Co. installation is a typical example of modern pusher-type recirculating furnaces for heat treating.

Type "G" Motorblowers are a logical source of combustion air in such installations, for they have the built-in qualities that are necessary for dependable, trouble-free operation.

Specify Type "G" MOTORBLOWERS

PRESSURE: ½ to 2¼ lb. POWER: 2 to 30 hp.
VOLUME: 100 to 4500 cfm. BULLETIN: Form 2671-B

Turbo Blowers up to 14500 hp.

Ingersoll-Rand

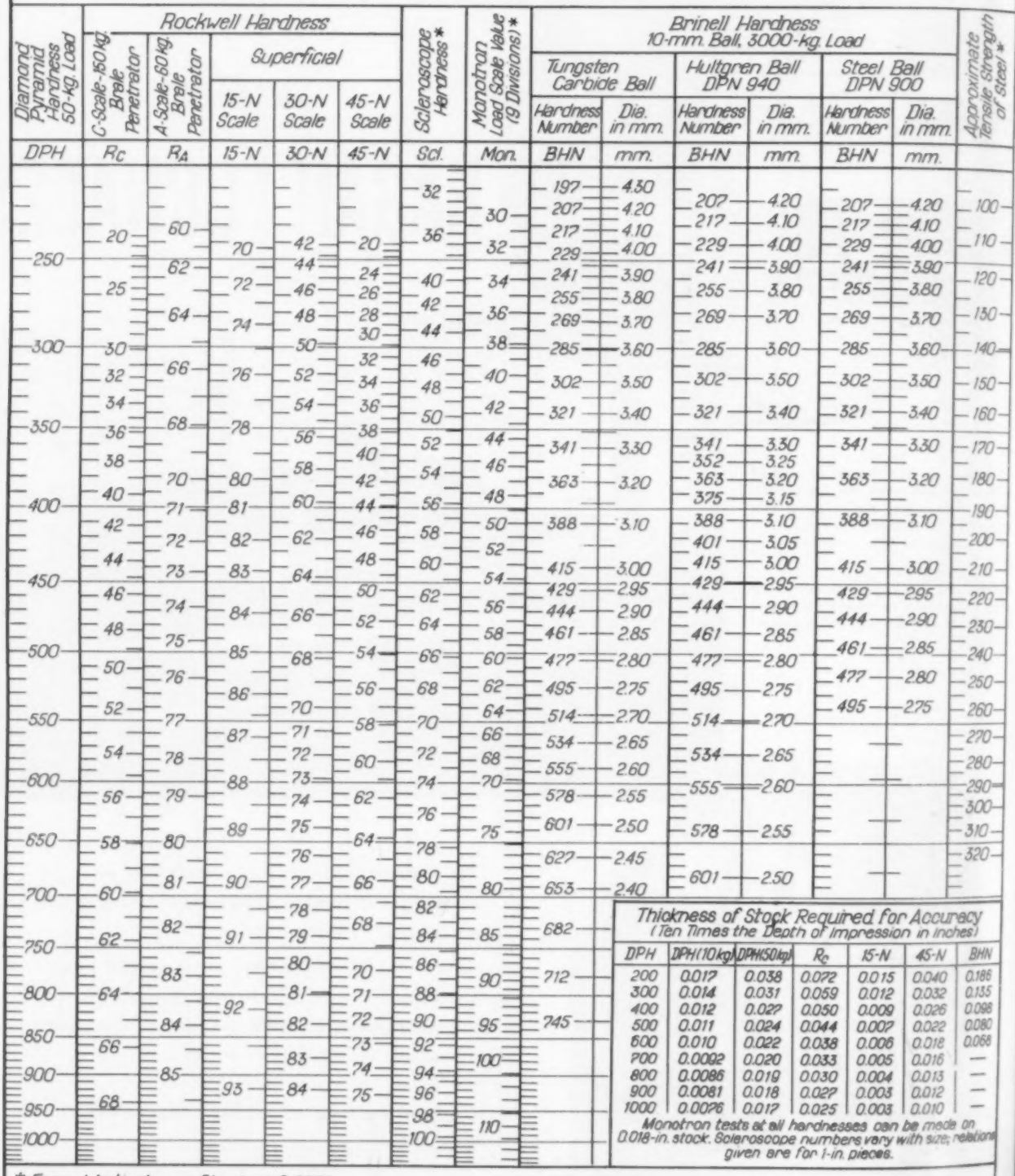
11 BROADWAY, NEW YORK 4, N. Y.

12-362

COMPRESSORS • AIR TOOLS • ROCK DRILLS • TURBO BLOWERS • CONDENSERS • CENTRIFUGAL PUMPS • OIL AND GAS ENGINES

Hardness Conversions for Hardened Steel

Tentative Values Suggested by Committee E-1, A.S.T.M., Adapted From Original Work by Howard Scott and T. H. Grav, Westinghouse Electric & Mfg. Co.



Thickness of Stock Required for Accuracy
(Ten Times the Depth of Impression in Inches)

DPH	DPH (10 kg)	DPH (50 kg)	R_C	15-N	45-N	BHN
200	0.017	0.038	0.072	0.015	0.040	0.186
300	0.014	0.031	0.059	0.012	0.032	0.135
400	0.012	0.027	0.050	0.009	0.026	0.098
500	0.011	0.024	0.044	0.007	0.022	0.080
600	0.010	0.022	0.038	0.006	0.018	0.068
700	0.0092	0.020	0.033	0.005	0.016	—
800	0.0086	0.019	0.030	0.004	0.013	—
900	0.0081	0.018	0.027	0.003	0.012	—
1000	0.0076	0.017	0.025	0.003	0.010	—

Monotron tests at all hardnesses can be made on 0.018-in. stock. Sclerascope numbers vary with size; relations given are for 1-in. pieces.

* From Westinghouse Standard S 502.1

In operating any test machine, follow manufacturer's instructions and check frequently against test blocks. Major causes of discrepancy: *(a)* Decarburized skin, *(b)* specimens too thin, *(c)* off-standard indenters, *(d)* inaccuracy of machine.

Above conversions are for steel, irrespective of composition and structure, up to its maximum hardness, and for any other material having about 30,000,000 psi. elastic modulus, uniform in depth to bottom of impression. (An exception is that Rockwell test values for shallow hardened steel may be 1 or 2 points higher than by conversion from *DPH*.)

For sintered carbides (*DPH* 900 to 1700) with much higher modulus the relations between *DPH* and R_c may be computed from $DPH = \frac{2.445 \times 10^6}{(B - R_c)^2}$ wherein constant B is 118 for carbide (120 for steel).

HAVE YOU LICKED 'EM?

•In Your *War* Production?
•For Your *Postwar* Production?

As compared with alkalis, trichlorothelene and ordinary "emulsions"—Solventol offers four distinctly new phases in the development of "solvents in water" mechanisms: (1) *complete* breakdown and removal of *all* soil, grease and grit; (2) *complete* rinsing; (3) freedom from *all* surface reaction; (4) *protection* of surfaces between operations . . . against rust, corrosion and finger printing.

Solventol synthetic-organic fluids for *all* metal parts washing . . . have been developed through 14 years of unique research. Solventol processes are the choice of top war producers . . . and postwar leaders. Complete layouts, washing equipment, process engineering instruction and follow-through . . . are included in our national service.

•See Us at Space E-610, National Metal Congress

SOLVENTOL

NEW METAL CLEANING - PLUS PROTECTION

SOLVENTOL CHEMICAL PRODUCTS, INC., DETROIT 3, MICHIGAN

Engineering Properties of "A" Nickel

Data from International Nickel Co., Inc.

WROUGHT NICKEL used throughout American industry is commercially pure metal, specifically "A" nickel to distinguish it from electrolytic nickel and from special alloys like "D" nickel containing 4.5% manganese and from "Z" nickel, a hardenable alloy containing 98.5% nickel.

Composition of "A" Nickel

	Wrought	Cast
Nickel (plus cobalt)	99.4	96.7
Copper	0.1	0.35
Iron	0.15	0.5
Manganese	0.2	0.45
Silicon	0.05	1.5
Carbon*	0.1	0.5

*A low carbon variety (0.01 to 0.02%) is known as "carbon-free nickel".

Magnetic Properties

At field strength of 100 gilberts per cm.	
Induction, gausses	5800
Permeability, μ	60
At magnetic induction B = 10,000 gausses:	
Coercive force, gilberts per cm.	5.2
Retentivity, gausses	2450
Hysteresis, ergs per cc. per cycle	5600

Tensile Properties at Elevated Temperatures

Test Temperature	Tensile Strength	Yield Strength (0.2% offset)	Elongation in 2 in.
300° F	75,000	22,000	48%
400	75,000	21,000	45
600	79,000	21,000	47
700	82,000	21,000	47
800	77,000	20,000	51
1000	40,000	17,000	51
1200	33,000	15,000	51
1500	22,000	9,000	63
1775	7,000	.....	91

Physical Constants of "A" Nickel

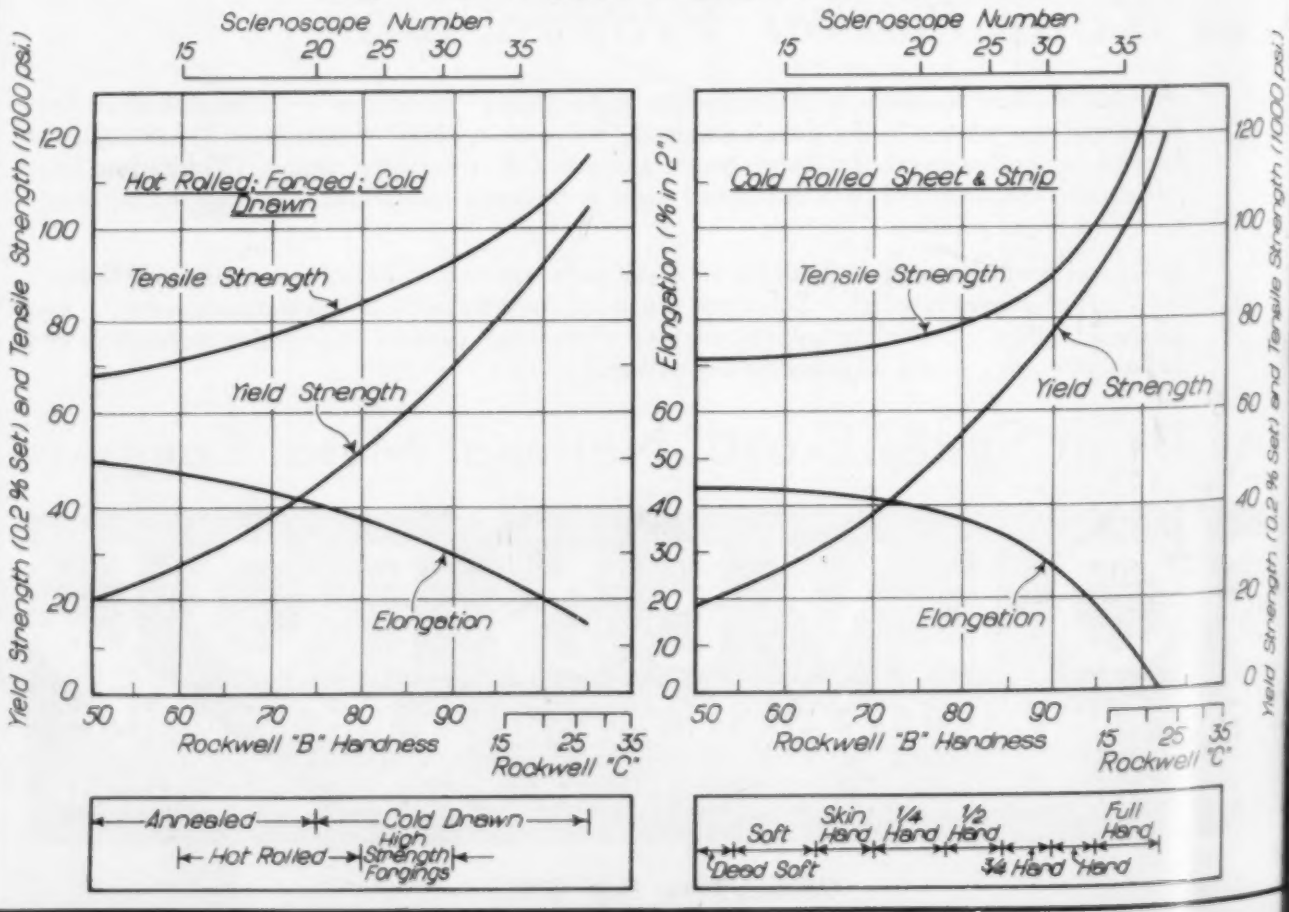
Specific gravity	8.85
Density, lb. per cu. in.	0.319
Melting point	
degrees Fahrenheit	2615 to 2635
degrees Centigrade	1435 to 1445
Specific heat at (80° to 212° F.) (27° to 100° C.)	0.130
Heat expansion coefficient	
at (80° to 212° F.), per ° F.	0.0000072
at (27° to 100° C.), per ° C.	0.000013
Thermal conductivity	
at (80° to 212° F.), Btu./sq.ft./hr./° F./in.	420
at (27° to 100° C.), cal./sq.cm./sec./° C./cm.	0.145
Electrical resistivity	
at 32° F., ohms/circ. mil. ft.	63
at 0° C., microhms/cm.³	10.45
Temperature coefficient of electrical resistivity	
per ° F.	0.0022 to 0.0028
per ° C.	0.0041 to 0.0051
Modulus of elasticity	
in tension, psi.	30,000,000
in torsion, psi.	11,000,000
Poisson's ratio	0.31

Fatigue and Corrosion Fatigue Limits*

No. of Cycles to Failure	Cold Drawn Rod Tested in			Annealed Rod Tested in		
	Air	Fresh Water	Sea Water	Air	Fresh Water	Sea Water
10^4	109	110	..	..	..	..
10^5	84	80	..	52	52	52
10^6	63	56	54	40	39	37
10^7	52	34	30	34	27	24
10^8	50	26	23	33	23	21
10^9	50	24	21	33	23	21

*The stress given is the stress to cause failure, in 1000 psi., in one direction only. The method of testing causes stress to vary from these values in tension to the same values in compression, and return, during each cycle of operation.

Average Tensile Properties and Hardness of Wrought Nickel



THERE'S NO ELIXIR TO CURE YOUR CLEANING PROBLEMS

IT'S REALLY pH THAT DOES THE JOB!

Kelite has developed scientific cleaning and processing through pH Control. pH Control is the "yardstick of chemistry." Just as degrees Fahrenheit are a measurement of temperature, or inches a measurement of lineal distance, or pounds a measurement of weight—so pH is a measurement of cleaning effectiveness when used in the copyrighted Kelite method.

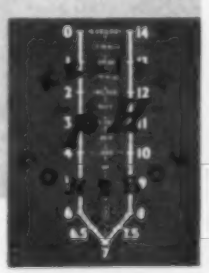
Soil, grease, corrosion, paint, rust stains, yes, in fact every substance in the universe has a definite location on the Kelite pH chart. Thus it is simple to select the material of correct pH value to reduce contamination to a neutral state, or to break the adhesion of an undersirable coating, or to dissolve a substance so that it may be easily rinsed away.

Every Kelite Service Engineer is equipped to do pH testing right in your plant. His demonstration may seem like sheer magic to you, but he is really only applying a modern scientific principle to the age-old problem of cleaning.

Kelite invites your inquiry.

KELITE

INDUSTRIAL CHEMICAL PROCESSES AND MATERIALS



Copyright 1944, KELITE PRODUCTS, INC. 909 E. 60th St., Los Angeles 1, Calif.

Mfg. Plants: Los Angeles, Chicago, Perth Amboy, Houston. Branches in principal cities.

Conversion Tables for Lengths

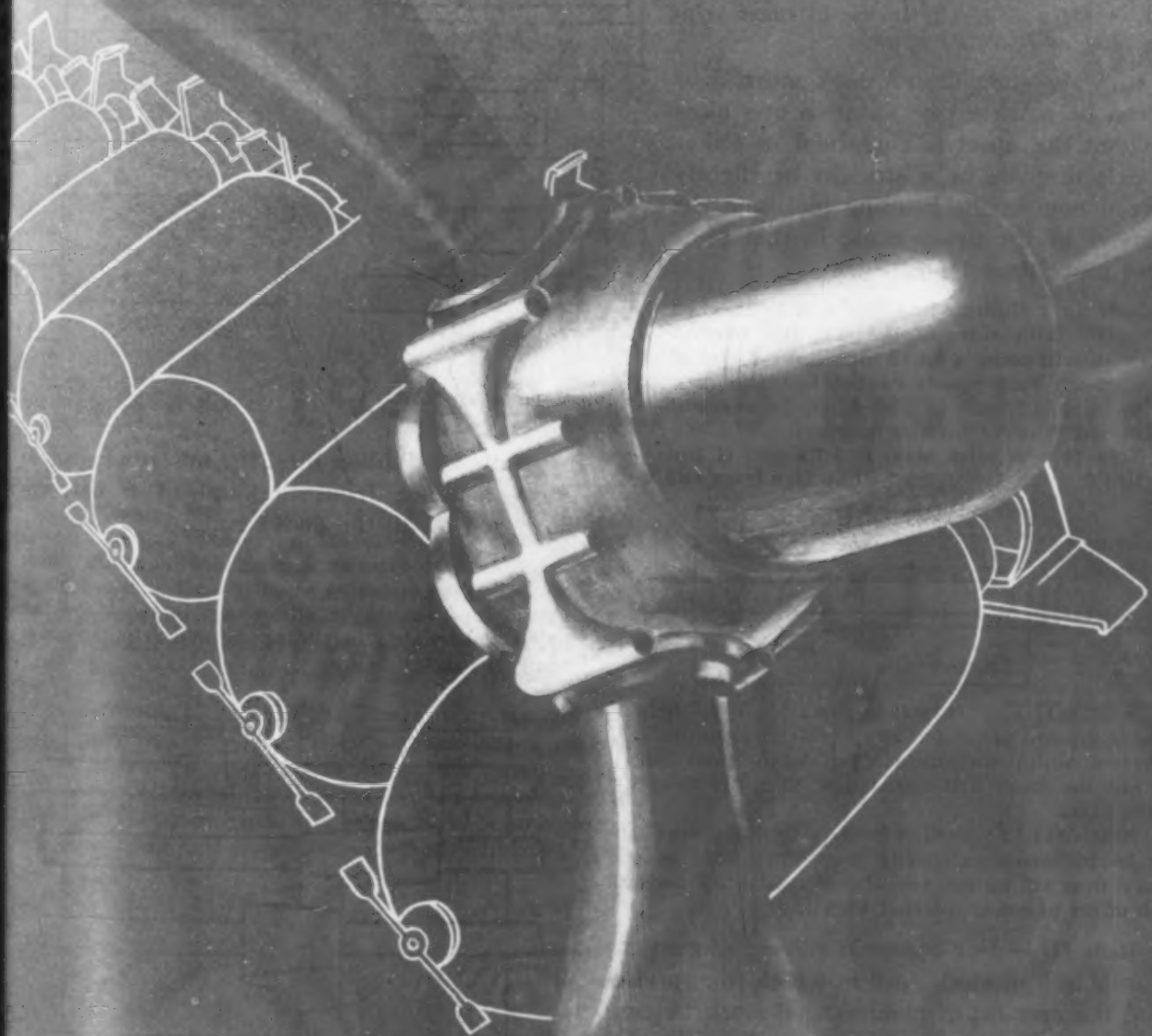
Based on value 1 m. = 39.37 in.

From "Ready Reference Tables", by Carl Hering

In. = / Mm. = / Feet = / M. = / Yd. = / Miles = / Km. =	millimeters	inches	meters	feet	meters	yards	kilometers	miles
1	25.400 1	0.039 370	0.304 801	3.280 83	0.914 402	1.093 61	1.609 35	0.621 37
2	50.800 1	0.078 740	0.609 601	6.561 67	1.828 80	2.187 22	3.218 69	1.242 74
3	76.200 2	0.118 110	0.914 402	9.842 50	2.743 21	3.280 83	4.828 04	1.864 11
4	101.600	0.157 480	1.219 20	13.123 3	3.657 61	4.374 44	6.437 39	2.485 48
5	127.000	0.196 850	1.524 00	16.404 2	4.572 01	5.468 06	8.046 74	3.106 85
6	152.400	0.236 220	1.828 80	19.685 0	5.486 41	6.561 67	9.656 08	3.728 22
7	177.800	0.275 590	2.133 60	22.965 8	6.400 81	7.655 28	11.265 4	4.349 59
8	203.200	0.314 960	2.438 40	26.246 7	7.315 21	8.748 89	12.874 8	4.970 96
9	228.600	0.354 330	2.743 21	29.527 5	8.229 62	9.842 50	14.484 1	5.592 33
10	254.001	0.393 700	3.048 01	32.808 3	9.144 02	10.936 1	16.093 5	6.213 70
11	279.401	0.433 070	3.352 81	36.089 2	10.058 4	12.029 7	17.702 8	6.835 07
12	304.801	0.472 440	3.657 61	39.370 0	10.972 8	13.123 3	19.312 2	7.456 44
13	330.201	0.511 810	3.962 41	42.650 8	11.887 2	14.216 9	20.921 5	8.077 81
14	355.601	0.551 180	4.267 21	45.931 7	12.801 6	15.310 6	22.530 9	8.699 18
15	381.001	0.590 550	4.572 01	49.212 5	13.716 0	16.404 2	24.140 2	9.320 55
16	406.401	0.629 920	4.876 81	52.493 3	14.630 4	17.497 8	25.749 6	9.941 92
17	431.801	0.669 290	5.181 61	55.774 2	15.544 8	18.591 4	27.358 9	10.563 3
18	457.201	0.708 660	5.486 41	59.055 0	16.459 2	19.685 0	28.968 2	11.184 7
19	482.601	0.748 030	5.791 21	62.335 8	17.373 6	20.778 6	30.577 6	11.806 0
20	508.001	0.787 400	6.096 01	65.616 7	18.288 0	21.872 2	32.186 9	12.427 4
21	533.401	0.826 770	6.400 81	68.897 5	19.202 4	22.965 8	33.196 3	13.048 8
22	558.801	0.866 140	6.705 61	72.178 3	20.116 8	24.059 4	35.405 6	13.670 1
23	584.201	0.905 510	7.010 41	75.459 2	21.031 2	25.153 1	37.015 0	14.291 5
24	609.601	0.944 880	7.315 21	78.740 0	21.945 6	26.246 7	38.624 3	14.912 9
25	635.001	0.984 250	7.620 02	82.020 8	22.860 0	27.340 3	40.233 7	15.534 2
26	660.401	1.023 62	7.924 82	85.301 7	23.774 4	28.433 9	41.843 0	16.155 6
27	685.801	1.062 99	8.229 62	88.582 5	24.688 9	29.527 5	43.452 4	16.777 0
28	711.201	1.102 36	8.534 42	91.863 3	25.603 3	30.621 1	45.061 7	17.398 4
29	736.601	1.141 73	8.839 22	95.144 2	26.517 7	31.714 7	46.671 1	18.019 7
30	762.002	1.181 10	9.144 02	98.425 0	27.432 1	32.808 3	48.280 4	18.641 1
31	787.402	1.220 47	9.448 82	101.706	28.346 5	33.901 9	49.889 8	19.262 5
32	812.802	1.259 84	9.753 62	104.987	29.260 9	34.995 6	51.499 1	19.883 8
33	838.202	1.299 21	10.058 4	108.268	30.175 3	36.089 2	53.108 5	20.505 2
34	863.602	1.338 58	10.363 2	111.548	31.089 7	37.182 8	54.717 8	21.126 6
35	889.002	1.377 95	10.668 0	114.829	32.004 1	38.276 4	56.327 2	21.747 9
36	914.402	1.417 32	10.972 8	118.110	32.918 5	39.370 0	57.936 5	22.369 3
37	939.802	1.456 69	11.277 6	121.391	33.832 9	40.463 6	59.545 8	22.990 7
38	965.202	1.496 06	11.582 4	124.672	34.747 3	41.557 2	61.155 2	23.612 1
39	990.602	1.535 43	11.887 2	127.953	35.661 7	42.650 8	62.764 5	24.233 4
40	1 016.00	1.574 80	12.192 0	131.233	36.576 1	43.744 4	64.373 9	24.854 8
41	1 041.40	1.614 17	12.496 8	134.514	37.490 5	44.838 1	65.983 2	25.476 2
42	1 066.80	1.653 54	12.801 6	137.795	38.404 9	45.931 7	67.592 6	26.097 5
43	1 092.20	1.692 91	13.106 4	141.076	39.319 3	47.025 3	69.201 9	26.718 9
44	1 117.60	1.732 28	13.411 2	144.357	40.233 7	48.118 9	70.811 3	27.340 3
45	1 143.00	1.771 65	13.716 0	147.638	41.148 1	49.212 5	72.420 6	27.961 6
46	1 168.40	1.811 02	14.020 8	150.918	42.062 5	50.306 1	74.030 0	28.583 0
47	1 193.80	1.850 39	14.325 6	154.199	42.976 9	51.399 7	75.639 3	29.204 4
48	1 219.20	1.889 76	14.630 4	157.480	43.891 3	52.493 3	77.248 7	29.825 8

In. = / Mm. = / Feet = / M. = / Yd. = / Miles = / Km. =	millimeters	inches	meters	feet	meters	yards	kilometers	miles
51	1 295.40	2.007 87	15.544 8	167.323	46.634 5	55.774 2	82.076 7	31.689 9
52	1 320.80	2.047 24	15.849 6	170.603	47.548 9	56.867 8	83.686 1	32.311 2
53	1 346.20	2.086 61	16.154 4	173.884	48.463 3	57.961 4	85.295 4	32.932 6
54	1 371 60	2.125 98	16.459 2	177.165	49.377 7	59.055 0	86.904 7	33.554 0
55	1 397.00	2.165 35	16.764 0	180.446	50.292 1	60.148 6	88.514 1	34.175 3
56	1 422.40	2.204 72	17.068 8	183.727	51.206 5	61.242 2	90.123 4	34.796 7
57	1 447.80	2.244 09	17.373 6	187.008	52.120 9	62.335 8	91.732 8	35.418 1
58	1 473.20	2.283 46	17.678 4	190.288	53.035 3	63.429 4	93.342 1	36.039 5
59	1 498.60	2.322 83	17.983 2	193.569	53.949 7	64.523 1	94.951 5	36.660 8
60	1 524.00	2.362 20	18.288 0	196.850	54.864 1	65.616 7	96.560 8	37.282 2
61	1 549.40	2.401 57	18.592 8	200.131	55.778 5	66.710 3	98.170 2	37.903 6
62	1 574.80	2.440 94	18.897 6	203.412	56.692 9	67.803 9	99.779 5	38.524 9
63	1 600.20	2.480 31	19.202 4	206.693	57.607 3	68.897 5	101.389	39.146 3
64	1 625.60	2.519 68	19.507 2	209.973	58.521 7	69.991 1	102.998	39.767 7
65	1 651.00	2.559 05	19.812 0	213.254	59.436 1	71.084 7	104.608	40.389 0
66	1 676.40	2.598 42	20.116 8	216.535	60.350 5	72.178 3	106.217	41.010 4
67	1 701.80	2.637 79	20.421 6	219.816	61.264 9	73.271 9	107.826	41.631 8
68	1 727.20	2.677 16	20.726 4	223.097	62.179 3	74.365 6	109.436	42.253 2
69	1 752.60	2.716 53	21.031 2	226.378	63.093 7	75.459 2	111.045	42.874 5
70	1 778.00	2.755 90	21.336 0	229.658	64.008 1	76.552 8	112.654	43.495 9
71	1 803.40	2.795 27	21.640 8	232.939	64.922 5	77.646 4	114.264	44.117 3
72	1 828.80	2.834 64	21.945 6	236.220	65.836 9	78.740 0	115.873	44.738 6
73	1 854.20	2.874 01	22.250 4	239.501	66.751 3	79.833 6	117.482	45.360 0
74	1 879.60	2.913 38	22.555 2	242.782	67.665 7	80.927 2	119.092	45.981 4
75	1 905.00	2.952 75	22.860 0	246.063	68.580 1	82.020 8	120.701	46.602 7
76	1 930.40	2.992 12	23.164 8	249.343	69.494 5	83.114 4	122.310	47.224 1
77	1 955.80	3.031 49	23.469 6	252.624	70.408 9	84.208 1	123.920	47.845 5
78	1 981.20	3.070 86	23.774 4	255.905	71.323 3	85.301 7	125.529	48.466 9
79	2 006.60	3.110 23	24.079 2	259.186	72.237 7	86.395 3	127.138	49.088 2
80	2 032.00	3.149 60	24.384 0	262.467	73.152 1	87.488 9	128.748	49.709 6
81	2 057.40	3.188 97	24.688 8	265.748	74.066 5	88.582 5	130.357	50.331 0
82	2 082.80	3.228 34	24.993 6	269.028	74.981 0	89.676 1	131.966	50.952 3
83	2 108.20	3.267 71	25.298 4	272.309	75.895 4	90.769 7	133.576	51.573 7
84	2 133.60	3.307 08	25.603 3	275.590	76.809 8	91.863 3	135.185	52.195 1
85	2 159.00	3.346 45	25.908 1	278.871	77.724 2	92.956 9	136.795	52.816 4
86	2 184.40	3.385 82	26.212 9	282.152	78.638 6	94.050 6	138.404	53.437 8
87	2 209.80	3.425 19	26.517 7	285.433	79.553 0	95.144 2	140.013	54.059 2
88	2 235.20	3.464 56	26.822 5	288.713	80.467 4	96.237 8	141.623	54.680 6
89	2 260.60	3.503 93	27.127 3	291.994	81.381 8	97.331 4	143.232	55.301 9
90	2 286.00	3.543 30	27.432 1	295.275	82.296 2	98.425 0	144.841	55.923 3
91	2 311.40	3.582 67	27.736 9	298.556	83.210 6	99.518 6	146.451	56.544 7
92	2 336.80	3.622 04	28.041 7	301.837	84.125 0	100.612	148.060	57.166 0
93	2 362.20	3.661 41	28.346 5	305.118	85.039 4	101.706	149.669	57.787 4
94	2 387.60	3.700 78	28.651 3	308.398	85.953 8	102.799	151.279	58.408 8
95	2 413.00	3.740 15	28.956 1	311.679	86.868 2	103.893	152.888	59.030 1
96	2 438.40	3.779 52	29.260 9	314.960	87.782 6	104.987	154.497	59.651 5
97	2 463.80	3.818 89	29.565 7	318.241	88.697 0	106.080	156.107	60.272 9
98	2 489.20	3.858 26	29.870 5	321.522	89.611 4	107.174	157.716	60.894 2

metal working, welding & forging



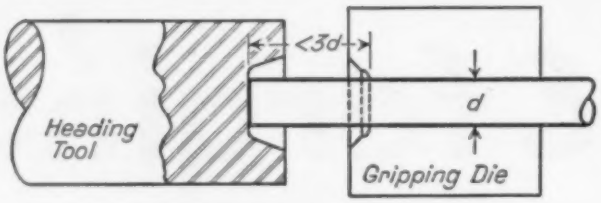
annual reference issue

october 1944

Rules Governing Forging Machine Dies

(Adapted from E. R. Frost; Courtesy National Machinery Co.)

Rule I— The limiting length of unsupported stock that can be gathered or upset in one blow without injurious buckling is three diameters.

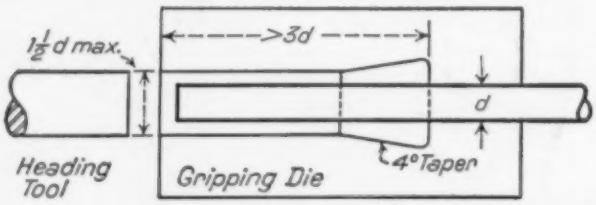


Note (*a*): A safer maximum length is $2\frac{1}{2}d$; little attention need be paid to squareness of end if $l=2d$. If $l>3d$, buckling will occur near the middle of the unsupported length. These principles hold irrespective of whether the stock overhangs the face of the gripping dies, or whether any portion is gathered in either gripping dies, heading tool or both.

Rule II— Lengths of stock more than $3d$ can be gathered or upset in one blow provided the upset is contained in either the gripping die or a straight or slightly tapered hole in the heading tool, and the diameter of the upset made in that blow is not more than $1\frac{1}{2}d$.

Note (*a*): Multiple buckling will be checked by contact with sides of the die, and friction therewith will cause a fin to form around end of upset. Such long upsets cannot be made half in one die and half in the other, for central buckle will receive no side support.

Note (*b*): A safer max. is $1.3d$, and if Rule I is also applied, the upset will be free from end fins.



Note (*c*): For very long upsets, it is helpful to have the end of the bar at a lower temperature, and to have a minimum diameter upset for the outer half of the die, the inner half tapering 4° to wider diameter at the base.

Note (*d*): In upsetting tubing, wall thickness cannot be increased externally more than 25% at one blow; internal upsets are almost unlimited because arch effect prevents internal buckling.

Rule III— For upsets requiring more than $3d$ in length of stock, and in which the upset is $1\frac{1}{2}d$, the amount of unsupported stock beyond the face of the die must not exceed $1d$ (operation 1, at right).

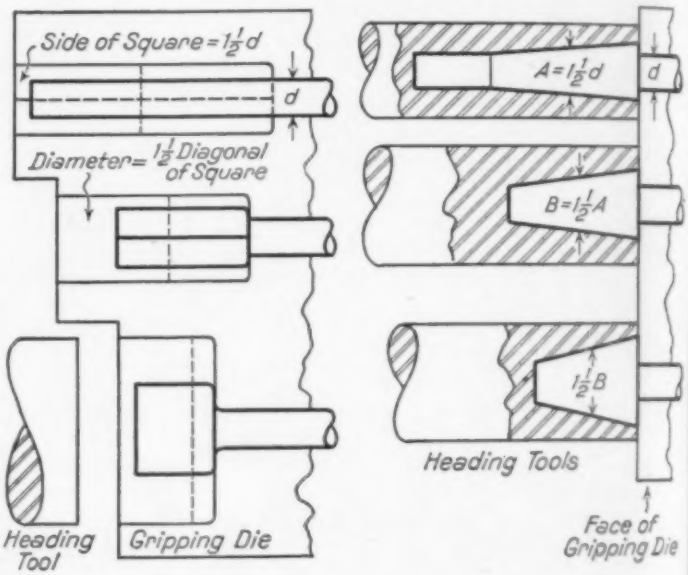
Note (*a*): Unsupported stock can amount to $1\frac{1}{2}\ d$ if diameter of upset is reduced to $1\frac{1}{4}\ d$.

Rule IV— Large amounts of stock can be gathered by multiple application of Rule II and III, and by using square or tapered impressions.

Note (*a*): In making the wide flange in sketch at left, below, the first and second impressions are within the $1\frac{1}{2}\ d$ limit, but the third, being a short upset under Rule I, is unlimited in diameter.

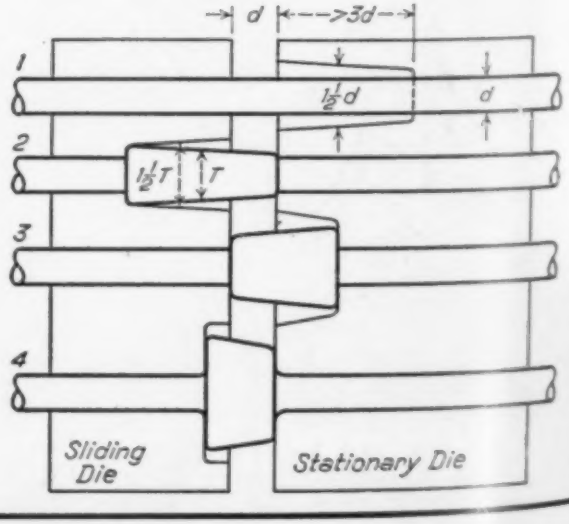
Note (*b*): The side of the square may be $1\frac{1}{2}\ d$ of the original bar, and the diameter of the next round may be $1\frac{1}{2}$ times the diagonal of the square.

Note (*c*): Tapered holes are proportioned as to their diameters at midlength of unsupported stock.



Rule V— Sliding dies, for upsetting stock at some distance from the end of a bar, are governed by all the above rules.

Note (*a*): Friction along the sides of the sliding die will favor upsetting near its front end, so multiple impressions should be alternately in front and rear half, or alternately in sliding die and gripping die, as shown in sketch below.



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Toolsteels for Hot Working Iron and Steel

By H. E. Replogle, Universal-Cyclops Steel Corp.

Requirements for All Hot Work Tools:

1. Sufficient toughness to resist working stresses.
2. Of such composition and in such heat treated condition as to resist softening when in service.
3. To have adequate wear resisting properties to assure normal, economical life.
4. Of such composition and heat treated condition as to wholly or partially resist the tendency towards heat or fire checking.

Influence of Design:

1. Wedge designs, sharp corners and thin sections promote chances of breakage and require inherently tougher compositions, usually secured through lower total alloy content steels.
2. Designs including raised sections partially or wholly buried in hot metal require higher red hardness and may not require as high toughness characteristics as other wedge designs.

Importance of Mechanical Set-Up:

1. All forging dies should be properly lined up.
2. Machines should be true to assure uniform application of pressure or impact.
3. Dies should be adjusted in hand fed and automatic forging machines to prevent excessive pressure on the faces of the dies, thus decreasing probability of fatigue failures.
4. Dies should not be mounted in worn or warped shoes or holders.

Importance of Adequate Preheating:

1. Well warmed dies and tools are less susceptible to cracking.
2. Minimum temperatures secured through use of buried unit heaters in certain types of drop forging dies prolong service life and retard heat checking.

Importance of Cooling:

1. Methods of cooling—Air, Oil, Water. Retards localized heating which may exert a tempering and softening action.
   - a—Air cooling least drastic—applicable to all types of tools. Also serves to blow away scale which, if present, will cause undue wear of dies.
   - b—Oil cooling—somewhat more severe and rapid but rarely detrimental to any tool or die.
   - c—Water cooling—most effective, but very drastic and often dangerous. When large dies attain high temperatures, water cooling tends to cause heat checking. Punches and small dies are often successfully cooled with an ample flow of water.

Influence of Die and Tool Lubrication:

1. Heavy graphite bearing greases serve as lubricants and prevent sticking. Usually assures better wear.

Quenching:

Among the data given below are recommendations as to the quenching medium; oil, air and "oil & air". The words "oil & air" signify an interrupted or timed quench, wherein a tool or die is quenched in oil to a temperature of about 1000° F., or where all color disappears; when this state is reached, the tool or die is removed and allowed to cool naturally in still air until cool enough to be handled in the bare hands. It should then be drawn as directed.

Recommended Compositions, Heat Treatments and Hardnesses

Analysis							Heat Treatment (°F.)				
C	Mn	Si	Cr	V*	W	Mo	Pre-Heat	High Heat	Quench	Draw	Brinell Hardness
Insert Dies in Upsetters											
0.55	0.25	....	1.25	0.20	2.75	....	1400	1750	Oil	1200	400 to 450
0.30	0.40	1.00	5.00	....	1.30	1.45	1400	1850	Air	1100	400 to 450
0.30	0.30	....	3.25	0.35	9.00	....	1450	2150	Oil & Air	1200	400 to 450
0.25	0.20	....	4.00	0.35	15.00	....	1550	2350	Oil & Air	1200	400 to 450
0.40	0.60	1.50	7.50	....	7.50	....	1550	2100	Oil	1250	400 to 450
Presses, Preloaded Dies											
0.40	0.30	....	1.75	0.20	11.00	....	1550	2150	Air	1100	539 to 578
0.45	0.30	....	2.75	0.35	15.00	....	1550	2200	Air	1150	539 to 578
Gripper Dies for Hand Fed Machines											
0.55	0.25	....	1.25	0.20	2.75	....	1200	1750	Oil	1100	450 to 500
0.30	0.30	....	3.25	0.35	9.00	....	1200	2150	Air	1150	450 to 500
0.55	0.30	0.40	4.00	1.00	....	0.50	1200	1650	Air	800	450 to 500
Gripper Dies for Automatic Machines											
0.30	0.40	1.00	5.00	....	1.30	1.45	1400	1850	Air	1050	444 to 526
0.55	0.35	....	4.00	1.00	....	0.50	1200	1625	Air	1000	444 to 526
Header Dies for Hand Fed Machines											
0.55	0.25	....	1.25	0.20	2.75	....	1200	1800	Oil	1225	430 to 461
0.30	0.30	....	3.25	0.35	9.00	....	1450	2150	Air	1175	430 to 461
0.30	0.40	1.00	5.00	....	1.30	1.45	1400	1850	Air	1100	400 to 450
0.40	0.60	1.50	7.50	....	7.50	....	1550	2100	Oil	1250	400 to 450
Header Dies for Automatic Machines											
0.55	0.25	....	1.25	0.20	2.75	....	1200	1800	Oil	1250	388 to 429
0.30	0.40	1.00	5.00	....	1.30	1.45	1400	1850	Air	1100	400 to 450
0.40	0.60	1.50	7.50	....	7.50	....	1550	2100	Oil	1250	400 to 450
Forging Punches											
0.30	0.30	....	3.25	0.35	9.00	....	1500	2250	Oil & Air	1175	425 to 450
0.30	0.40	1.00	5.00	....	1.30	1.45	1400	1850	Air	1100	400 to 450
0.40	0.60	1.50	7.50	....	7.50	....	1550	2100	Oil	1250	400 to 450

Above data do not represent all of the types being used for the various applications listed, nor the only heat treatments or hardness values for these types. Neither do the above listings include flat, cut and swaging dies used in beam, steam or air hammers. However, the list represents the broadest general selections used commercially in the services noted.

*Vanadium was eliminated from these analyses by order of War Production Board during 1942 and part of 1943. However, these restrictions were removed by Order M-21-H Aug. 4, 1943, and analyses as shown are now permissible, but still subject to limitation as to use.

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(Patent No. 2,122,691)

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Standard Tolerances for Forgings up to 100 Lb.

Summary of Standards Adopted by Drop Forging Association, 1937

TOLERANCES, within the scope of these standards, shall be either "special" or "regular."

Special tolerances are those particularly noted on the drawings or in the specifications, and apply only to the particular dimension or thing noted. They may state any or all tolerances in any way as occasion may require. Regular tolerances apply in all other cases.

Regular tolerances in general forging practice are known as (*a*) "commercial standard," for general forging practice, or (*b*) if extra close work is desired involving additional expense and care in the production of forgings, "close standard" may be specified.

Class I—Thickness Tolerances

For drop hammer forgings, thickness tolerances shall apply to the overall thickness measured in a direction perpendicular to the fundamental parting plane of the dies.

For upset forgings, thickness tolerances shall apply to the metal actually enclosed and formed by the dies, measured parallel to the direction of travel of the ram.

Thickness Tolerances in Inches

Max. Net Weight	Commercial		Close	
	Minus	Plus	Minus	Plus
0.2	0.008	0.024	0.004	0.012
0.4	0.009	0.027	0.005	0.015
0.6	0.010	0.030	0.005	0.015
0.8	0.011	0.033	0.006	0.018
1	0.012	0.036	0.006	0.018
2	0.015	0.045	0.008	0.024
3	0.017	0.051	0.009	0.027
4	0.018	0.054	0.009	0.027
5	0.019	0.057	0.010	0.030
10	0.022	0.066	0.011	0.033
20	0.026	0.078	0.013	0.039
30	0.030	0.090	0.015	0.045
40	0.034	0.102	0.017	0.051
50	0.038	0.114	0.019	0.057
60	0.042	0.126	0.021	0.063
70	0.046	0.138	0.023	0.069
80	0.050	0.150	0.025	0.075
90	0.054	0.162	0.027	0.081
100	0.058	0.174	0.029	0.087

Class II—Width and Length Tolerances

Width and length tolerances shall be alike, and are classified in three subdivisions (*a*) shrinkage and die wear tolerance, (*b*) mismatching tolerance, (*c*) trimmed size tolerance.

For drop hammer forgings, width and length tolerances shall apply to the metal actually enclosed and formed by the die, as measured parallel to the fundamental parting plane of the dies.

For upset forgings, width and length tolerances shall apply to directions perpendicular to the direction of travel of the ram.

II(a)—Shrinkage and Die Wear Tolerances

See table below. These shall not be applied separately, but only as the sum of the two; they shall be measured in such a way as to eliminate draft or variation in draft. They apply to that part of the forging formed by a single die block, and to no dimension crossing the parting plane.

Shrinkage and Die Wear in Inches

Length or Width	Shrinkage		Max. Net Weight	Die Wear	
	Commercial + or −	Close + or −		Commercial + or −	Close + or −
1 in.	0.003	0.002	1 lb.	0.032	0.016
2 in.	0.006	0.003	3 lb.	0.035	0.018
3 in.	0.009	0.005	5 lb.	0.038	0.019
4 in.	0.012	0.006	7 lb.	0.041	0.021
5 in.	0.015	0.008	9 lb.	0.044	0.022
6 in.	0.018	0.009	11 lb.	0.047	0.024
For each additional inch add	0.003	0.0015	For each additional 2 lb. add	0.003	0.0015
For example:			For example:		
7 in.	0.021	0.011	13 lb.	0.050	0.026
12 in.	0.036	0.018	21 lb.	0.062	0.031
18 in.	0.054	0.027	31 lb.	0.077	0.039
24 in.	0.072	0.036	41 lb.	0.092	0.046
36 in.	0.108	0.054	51 lb.	0.107	0.054
48 in.	0.144	0.072	71 lb.	0.137	0.069
60 in.	0.180	0.090	91 lb.	0.167	0.084

II(b)—Mismatching Tolerance

Mismatching is the displacement of a point in that part of a forging formed by one die block of a pair, from its desired position when located from the part of the forging formed in the other die block of the pair, measured in a projection parallel to the fundamental parting plane of the dies. It does not include any displacement caused by variation in thickness of the forging; mismatching tolerances are independent of and in addition to any others.

Mismatching Tolerance in Inches

Max. Net Weight	Commercial	Close
1 lb.	0.015	0.010
7 lb.	0.018	0.012
13 lb.	0.021	0.014
19 lb.	0.024	0.016
For additional 6 lb. add	0.003	0.002
For example:		
37 lb.	0.033	0.022
55 lb.	0.042	0.028
79 lb.	0.054	0.036
97 lb.	0.063	0.042

II(c)—Trimmed Size Tolerances

The trimmed size shall not be greater nor less than the limiting sizes at the parting plane imposed by the sum of the draft angle tolerances and the shrinkage and die wear tolerances.

Class III—Draft Angle Tolerances in Degrees

	Drop Forgings		Upset Forgings	
	Outside	Inside Holes	Outside	Inside Holes
Nominal angle	7	7 or 10	3	5
Commercial limits	0 to 10	0 to 13	0 to 5	0 to 8
Close limits	0 to 8	0 to 8	0 to 4	0 to 7

Class IV—Quantity Tolerances

Any quantity shipped within the quoted limits of over-run or under-run shall be considered as completing each release or part shipment of an order. Limits are as follows:

Quantity Tolerances

Number on Order	Over-run	Under-run
1 to 2	1 piece	0
3 to 5	2 pieces	1 piece
6 to 19	3 pieces	1 piece
20 to 29	4 pieces	2 pieces
30 to 39	5 pieces	2 pieces
40 to 49	6 pieces	3 pieces
50 to 59	7 pieces	3 pieces
60 to 69	8 pieces	4 pieces
70 to 79	9 pieces	4 pieces
80 to 99	10 pieces	5 pieces
100 to 199	10%	5.0%
200 to 299	9%	4.5%
300 to 599	8%	4.0%
600 to 1,249	7%	3.5%
1,250 to 2,999	6%	3.0%
3,000 to 9,999	5%	2.5%
10,000 to 39,999	4%	2.0%
40,000 to 299,999	3%	1.5%
300,000+	2%	1.0%

Class V—Fillet and Corner Tolerances

Fillet and corner tolerances apply to all intersecting surfaces even though drawings or models indicate sharp corners. If such drawings or models have or indicate (even though actual dimensions are not specified) fillet or corner dimensions of larger radii than the following standards, such larger dimensions shall be considered as actually specified and the tolerances shall be "special tolerances."

Where a corner tolerance applies on the meeting of two drafted surfaces, the tolerance shall apply to the narrow end of such meeting and the radius will increase toward the wide end. The total increase in the radius will equal the length of the drafted surface in inches, multiplied by the tangent of the nominal draft angle.

Fillet and Corner Tolerances

Max. Net Weight	Commercial	Close
0.3 lb.	3/32	3/64
1 lb.	1/8	1/16
3 lb.	5/32	5/64
10 lb.	3/16	3/32
30 lb.	7/32	7/64
100 lb.	1/4	1/8

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Severity	Type of Machining Operation	Ferrous Metals; Steels and Irons				Non-Ferrous Metals	
		I; 70% Plus*	II; 50 to 70%*	III; 40 to 50%*	IV; Below 40%*	V; 100% Plus*	VI; Below 100%*
1. (Greatest)	Broaching; internal	Em. Sul. *(a)*	**Sul.** *(b)* Em.	**Sul.** Em.	**Sul.** Em.	MO. Em.	Sul. ML.
2.	Broaching; surface	Em. Sul.	**Em.** Sul.	**Sul.** Em.	**Sul.** Em.	MO. Em.	Sul. ML.
2.	Threading; pipe	Sul.	**Sul.** ML.	Sul.	Sul.		Sul. *(c)*
3.	Tapping; plain	Sul.	Sul.	Sul.	Sul.	Em. Dry	Sul. ML.
3.	Threading; plain	Sul.	Sul.	Sul.	Sul.	Em. Sul.	Sul.
4.	Gear shaving	Sul. L.	Sul. L.	Sul. L.	Sul. L.		
4.	Reaming; plain	ML. Sul.	ML. Sul.	ML. Sul.	ML. Sul.	ML. MO. Em.	ML. MO. Sul.
4.	Gear cutting *(d)*	Sul. ML. Em.	Sul.	Sul.	Sul. ML.		Sul. ML.
5.	Drilling; deep	**Em.** ML.	Sul. **Em.**	Sul.	Sul.	MO. ML. Em.	Sul. ML.
6.	Milling; plain	**Em.** ML. Sul.	Em.	Em.	Sul.	Em. MO. Dry	Sul. Em.
6.	Milling; multiple cutter	ML.	Sul.	Sul.	**Sul.** ML.	Em. MO. Dry	**Sul.** Em.
7.	Boring; multiple head	**Sul.** Em.	**Sul.** Em.	**Sul.** Em.	Sul. Em.	K. Dry Em.	Sul. Em.
7.	Multiple spindle automatic screw machines and turret lathes; drilling, forming, turning, reaming, cutting off, tapping, threading	Sul. Em. ML.	Sul. Em. ML.	Sul. Em. ML.	Sul. ML. Em.	Em. Dry ML.	Sul.
8.	High speed, light feed automatic screw machines; drilling, forming, tapping, threading, turning, reaming, box milling, cutting off	Sul. Em. ML.	Sul. Em. ML.	Sul. Em. ML.	Sul. ML. Em.	Em. Dry ML.	Sul.
9.	Drilling	Em.	Em.	Em.	Em. Sul.	Em. Dry	Em.
9.	Planing, shaping	**Em.** Sul. ML.	**Em.** Sul. ML.	Sul. **Em.**	**Em.** Sul.	Em. Dry	Em.
9.	Turning; single point tool form tools	Em. Sul. ML.	Em. Sul. ML.	Em. Sul. ML.	Em. Sul. ML.	Em. Dry ML.	Em. Sul.
10. (Least)	Sawing; circular, hack	Sul. ML. Em.	Sul. Em. ML.	Sul. Em. ML.	Sul. Em. ML.	Dry MO. Em.	Sul. Em. ML.
	Grinding; 1. plain	Em.	Em.	Em.	Em.	Em.	Em.
	2. form (thread, etc.)	Sul.	Sul.	Sul.	Sul.	MO. Sul.	Sul.

Symbols for Cutting Fluids

K.—Kerosene.
L.—Lard oil.
MO.—Mineral oils.
ML.—Mineral-lard oils.
Sul.—Sulphurized oils; see note *(a)*.
Em.—Soluble or emulsifiable oils and compounds.
Dry—No cutting fluid.

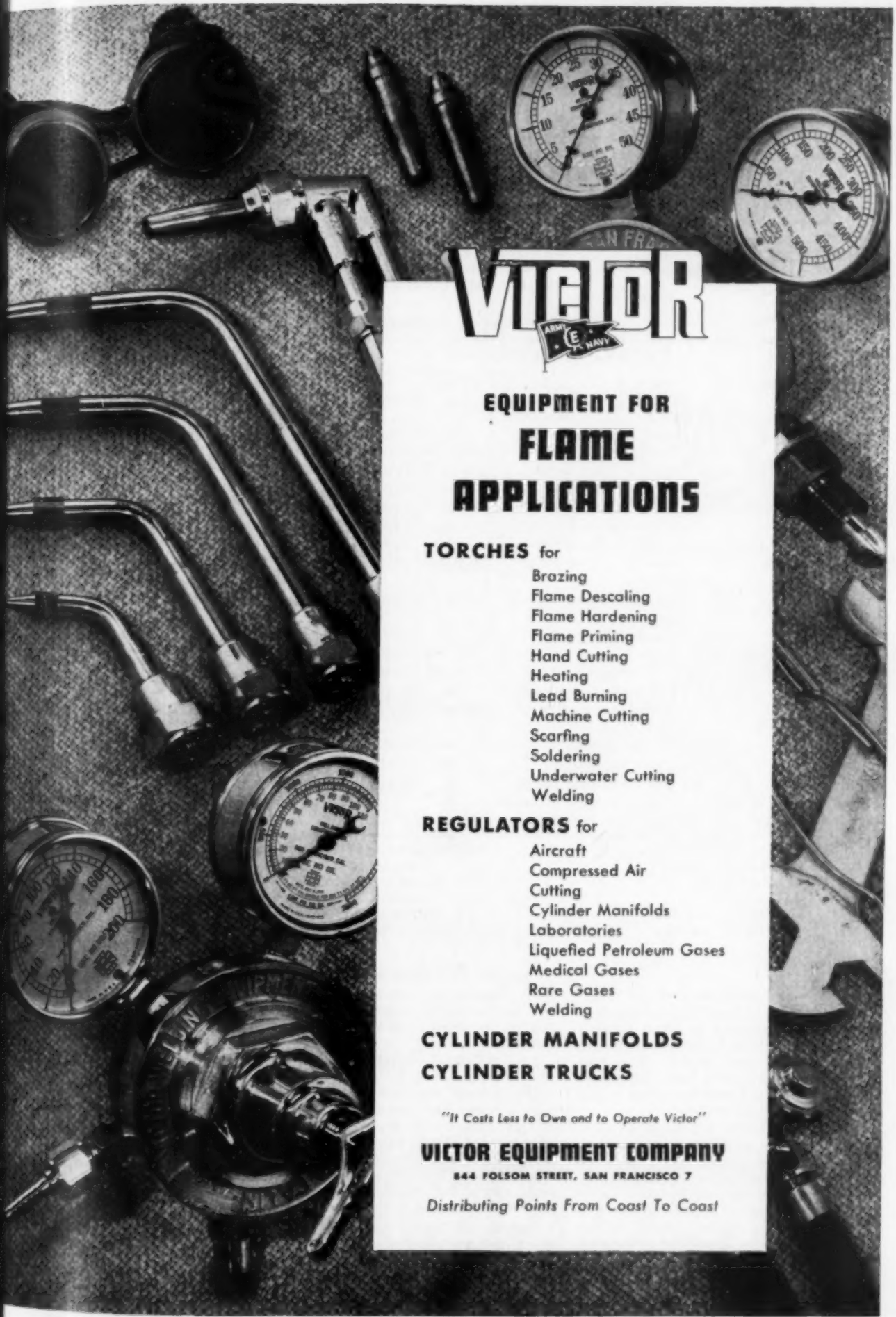
Notes: *Machinability rating based on 100% for cold drawn Bessemer screw stock (specification B 1112).

(a) Oils containing both sulphur and chlorine when carefully manufactured and sponsored may be used where sulphurized oils are indicated.

(b) Preferred recommendations are in **bold face** type.

(c) In threading copper, palm oil is frequently used.

(d) It is reported by several observers that emulsions are usually unsatisfactory on some precision machines, like Fellows gear shapers and Gleason gear generators.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Fluxes for Oxy-Acetylene Welding & Brazing

By Houston E. Landis, Jr., and F. C. Saacke

Apparatus Research & Development Dept., Air Reduction Sales Co., Jersey City, N. J.

General Flux Characteristics

Phase — Best applied to welding rod as a paste (suspension of powdered salts in water or alcohol). Sometimes applied as a dry powder or injected as a vapor into the welding atmosphere.

Melting Point — Below temperature where an appreciable amount of oxide forms on base metal.

Film — Uniform, quiescent, transparent.

Density — Light and easily floated; no tendency to be trapped in weld metal.

Viscosity at Welding Temperatures — Should be sufficient to keep the weld metal covered and protected from gas absorption and oxidation, but not so viscous as to prevent ready fusion of the welding rod and weld metal.

Oxide Solvent — Should readily dissolve base metal oxides as well as weld metal oxides and keep contact surfaces clean at welding temperatures. (Base metal should practically always be cleaned before welding.)

Weld Appearance — All the above characteristics should combine to permit the rapid deposition of a weld free from oxides, flux inclusions, or gas pockets with smooth, clean surfaces free from overlaps or pits.

Oxy-Acetylene Welding Procedures

Base Metal	Fusion Welding			Brazing		
	Filler Metal	Flame *(a)*	Flux	Filler Metal	Flame *(a)*	Flux
Lead	Same as base metal	N	None	...	...	...
Aluminum (soft)	Same as base metal	SR to N	Type A	Aluminum solder	N or R	None
Aluminum alloy (wrt.)	Same as base metal	SR to N	Type A	Aluminum solder	N or R	None
	Silicon-aluminum alloy	SR to N	Type A	...	...	...
Cast aluminum	Silicon-aluminum alloy	SR to N	Type B	...	...	...
Yellow brass	Similar to base metal	O	Type C	Silver alloy or phos-copper	SR to N	Type H
Red or leaded brass	High zinc brass *(b)*	N	Type C	Silver alloy or phos-copper	SR to N	Type H
Silicon bronze	Similar to base metal	N to SO	Type C	High zinc brass *(b)*	N to SO	Type C
				Silver alloy or phos-copper	SR to N	Type H
Copper	Deoxidized copper	N	None	High zinc brass *(b)*	N to SO	Type C
				Silver alloy or phos-copper	SR to N	Type H
Nickel	Same as base metal	R	None	Silver alloy	SR to N	Type H
Nickel-copper alloy	Same as base metal	N to SR	Type C	Silver alloy	SR to N	Type H
	Silicon-monel	N to SR	None			
Cast iron	Similar to base metal	N	Type F	High zinc brass *(b)*	N to SO	Type E
Malleable iron	White cast iron *(c)*	N to R	Type F	High zinc brass *(b)*	N to SO	Type C
Galvanized iron	...	..	..	High zinc brass *(b)*	N to SO	Type C
Carbon steel	Low carbon steel	N	None	High zinc brass *(b)*	N to SO	Type C or D
	Low alloy steel	SR	None	Silver alloy	SR to N	Type H
Alloy steel	Similar to base metal	SR	None	Silver alloy	SR to N	Type H
Stainless iron & steel	Similar to base metal *(d)*	N	Type G	Silver alloy	SR to N	Type H
High manganese steel	Similar to base metal	N to SR	None	...	...	...

(a)
N—Neutral
O—Oxidizing
R—Reducing
SR—Slightly reducing
SO—Slightly oxidizing

(b) High zinc (38 to 44%) brass with additions of alloying elements such as tin, iron, manganese, silicon, nickel.

(c) Fusion welding of malleable iron should be followed by re-malleableizing heat treatment.

(d) 18-8 stainless steels often alloyed and "stabilized" with columbium, titanium, molybdenum, tungsten.

Specific Flux Characteristics

Aluminum Rod

Type A — An aluminum welding flux composed generally of alkali halides; characterized chiefly by the speed with which solid welds in sheet metal may be made with smooth fusion at the root of the weld and without pitting or discoloration on the surface.

Type B — A modified aluminum welding flux with additions of higher melting point constituents like borates and other chemicals to provide greater slagging action as well as additional viscosity, resistance to oxidation, and protection while making repairs in cast aluminum parts by puddle welding.

Bronze Rod

Type C — An "oxidizing" flux ordinarily made with a boric acid base. It should form a thin but strong oxide film on the surface of the molten copper alloy, thereby preventing gas absorption and excessive oxidation. Recommended for clean or cleaned iron and steel surfaces.

Type D — Where oxidized, rusty, or dirty surfaces are to be joined, an "oxide solvent" flux ordinarily made with a borax base and having a high solvent action for metallic oxides is recommended. It should keep both the base metal and the molten puddle clean and bright. (Note: This flux will not give as good weld metal characteristics as the Type C flux applied to clean surfaces.)

Type E — A "highly oxidizing" brazing flux designed specifically for removing carbon or graphite from the surfaces of cast iron. Usually contains an oxidizing component such as manganese dioxide. (Note: This flux often used with the Type C flux to provide the proper tinning action.)

Cast Iron Rod

Type F — Ordinarily made with a borax base and containing alkali salts to aid in fluxing the slag that forms on cast iron. Should permit ready fusion of the welding rod and base metal without leaving gas pockets or inclusions.

Stainless Steel Rod

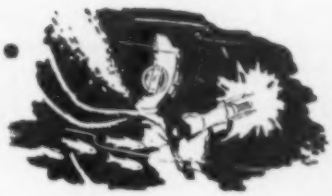
Type G — A stainless steel welding flux designed to permit complete fusion at the root of a weld without burning. The best test for a flux of this type is to coat the root of a butt joint with the paste and then observe the penetration at the root after making the weld.

Silver Brazing Alloy

Type H — A silver "soldering" flux made from an alkali bi-fluoride and borax or boric acid; gives the best results on both non-ferrous and ferrous alloys, including stainless.

Underwater Welding...

See how the Nelson Stud Welder is used for salvage work. Welding studs with gun submerged in salt water.



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Operates solely on DC current and requires only one cable. It's the answer to many industrial production problems.

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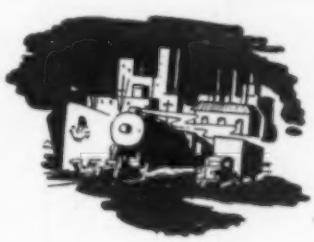
How stud welders are used on electrical transformers and equipment; boiler tubes; locomotive cabs; freight cars; securing metal lath and plaster; and heavy machinery manufacture, etc.



PLUS THESE FEATURES...

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- See cutaway views of many kinds and sizes of studs!
- See samples of all the uses developed to date for Nelson "Flux-filled" Studs.
- Free samples of stud welding!

NELSON STUD WELDERS & STUDS

—USED BY MORE THAN 460 INDUSTRIAL PLANTS AND SHIPYARDS!

Machinability Rating of Various Metals

By Independent Research Committee on Cutting Fluids

MACHINABILITY ratings are classed in four groups for irons and steels and two for non-ferrous alloys. Machinability is rated to nearest 5%, based on 100% rating for A.I.S.I. steel B1112, cold rolled or cold drawn Bessemer screw stock, machined with suitable cutting fluid at 180 ft. per min. under normal conditions as to tool life and surface finish. Hardness values indicate a desirable range and correspond to ordinary commercial deliveries.

*Denotes steel in mill-annealed condition.

(a) Numbers denote A.I.S.I. compositions, see page 666. For NE steels see page 672.

(b) High chromium-iron alloys, A.I.S.I. Type No. 416 or 430F.

(c) Spheroidize annealed by mill.

(d) A.I.S.I. Type No. 303; 18-8 of free machining type.

Class I, Ferrous, Rating 70% Plus

Specification *(a)*	Rating	Brinell
C 1110	85%	137 to 166
C 1115	85	143 to 179
C 1117	85	143 to 179
C 1118	80	143 to 179
C 1120	80	143 to 179
C 1132	75	187 to 229
C 1137	70	187 to 229
C 1022	70	159 to 192
C 1016	70	137 to 174
B 1111	95	179 to 229
B 1112	100	179 to 229
B 1113	135	179 to 229
A 4023	70	156 to 207
A 4027*	70	166 to 212
A 4119	70	170 to 217
Malleable (Ferritic)	100 to 250	120 to 200
(Pearlitic)	70	190 to 240
Cast steel (0.35% C)	70	170 to 212
Stainless "iron" *(b)*	70	163 to 207

Class II, Ferrous, Rating 50 to 65%

Specification	Rating	Brinell
C 1141 *(a)*	65	183 to 241
C 1020	65	137 to 174
C 1030	65	170 to 212
C 1035	65	174 to 217
C 1040*	60	179 to 229
C 1045*	60	179 to 229
A 2317	55	174 to 217
A 3045*	60	179 to 229
A 3120	60	163 to 207
A 3130*	55	179 to 217
A 3140*	55	187 to 229
A 3145*	50	187 to 235
A 4032*	65	170 to 229
A 4037*	65	179 to 229
A 4042*	60	183 to 235
A 4047*	55	183 to 235
A 4130*	65	187 to 229
A 4137*	60	187 to 229
A 4145*	55	187 to 229
A 4150*	50	187 to 235
A 4615	65	174 to 217
A 4640*	55	187 to 235
A 4815	50	187 to 229
A 5120	65	170 to 212
A 5140*	60	174 to 229
A 5150*	55	179 to 235
A 5045*	65	179 to 229
NE 8024	60	174 to 217
NE 8124	55	174 to 217
NE 8233*	60	179 to 229
NE 8339*	60	179 to 229
NE 8620	60	170 to 217
NE 8630*	65	179 to 229
NE 8724	65	179 to 229
NE 8739*	60	179 to 229
NE 8744*	55	183 to 235
NE 8749*	50	183 to 241
NE 8817	60	170 to 229

Class III, Ferrous, 40 to 50%

Specification	Rating	183 to 241
C 1008 *(a)*	50	
C 1010	50	
C 1015	50	
C 1050*	50	
C 1070*	45	
A 1320	50	170 to 229
A 1330*	50	179 to 235
A 1335*	50	179 to 235
A 1340*	45	179 to 235
A 2330*	50	179 to 229
A 2340*	45	179 to 235
A 3240*	45	183 to 235
A 4340*	45	187 to 241
A 6120	50	179 to 217
A 6145*	50	179 to 235
A 6152 *(c)*	45	183 to 241
A 9260*	45	187 to 255
NE 8442*	45	187 to 255
NE 8447*	40	187 to 255
NE 8949*	50	187 to 255
Ingot iron	50	101 to 131
Wrought iron	50	101 to 131
Stainless *(d)*	45	179 to 212
Cast iron	50	160 to 193

Class IV, Ferrous, Rating 40% or Below

Specification	Rating	Brinell
A 2515*	30	179 to 229
E 3310*	40	170 to 229
E 52100 *(c)*	30	183 to 229
Ni-Resist*	30	
Stainless 18-8*	25	
Manganese oil hardening steel *(c)*	30	
Toolsteel, low tungsten, chromium and carbon *(c)*	30	
High speed steel *(c)*	30	
High carbon, high chromium, toolsteel *(c)*	25	

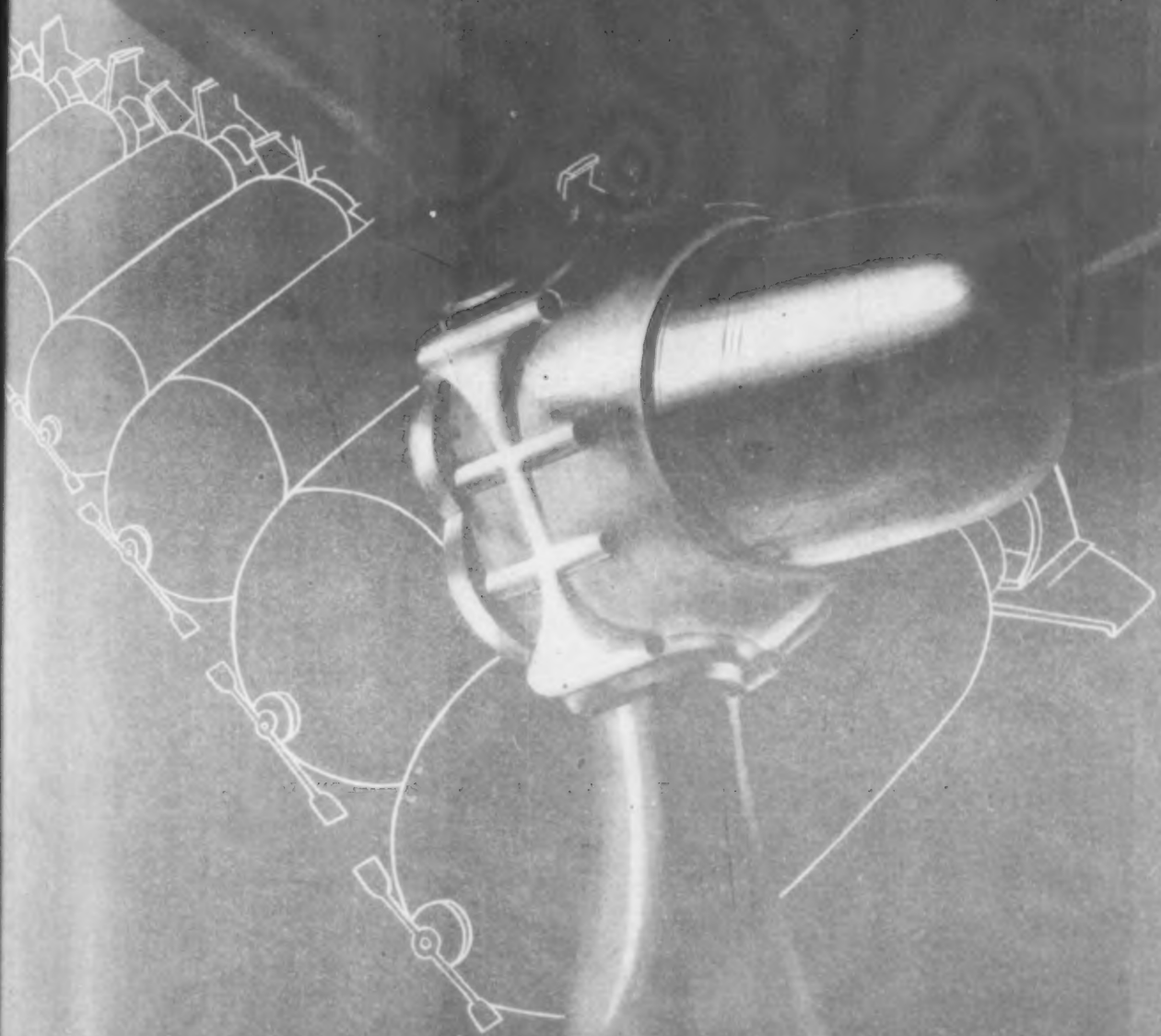
Class V, Non-Ferrous, Rating Above 100%

Alloy	Rating
Magnesium alloys	500 to 2000
Aluminum, 11-S *(e)*	500 to 2000
2-S *(e)*	300 to 1500
17-S *(e)*	300 to 1500
Brass, leaded	150 to 600
yellow	200
red	200
Bronze, lead bearing	200 to 500
Zinc	200

Class VI, Non-Ferrous, Rating Less Than 100%

Alloy	Rating
Gun metal	60
Bronze, manganese	40
Copper, cast	70
rolled	60
Nickel	20
Monel metal, cast	35
rolled	45
"K" Monel	50
Inconel	45
Everdur	60

testing & control

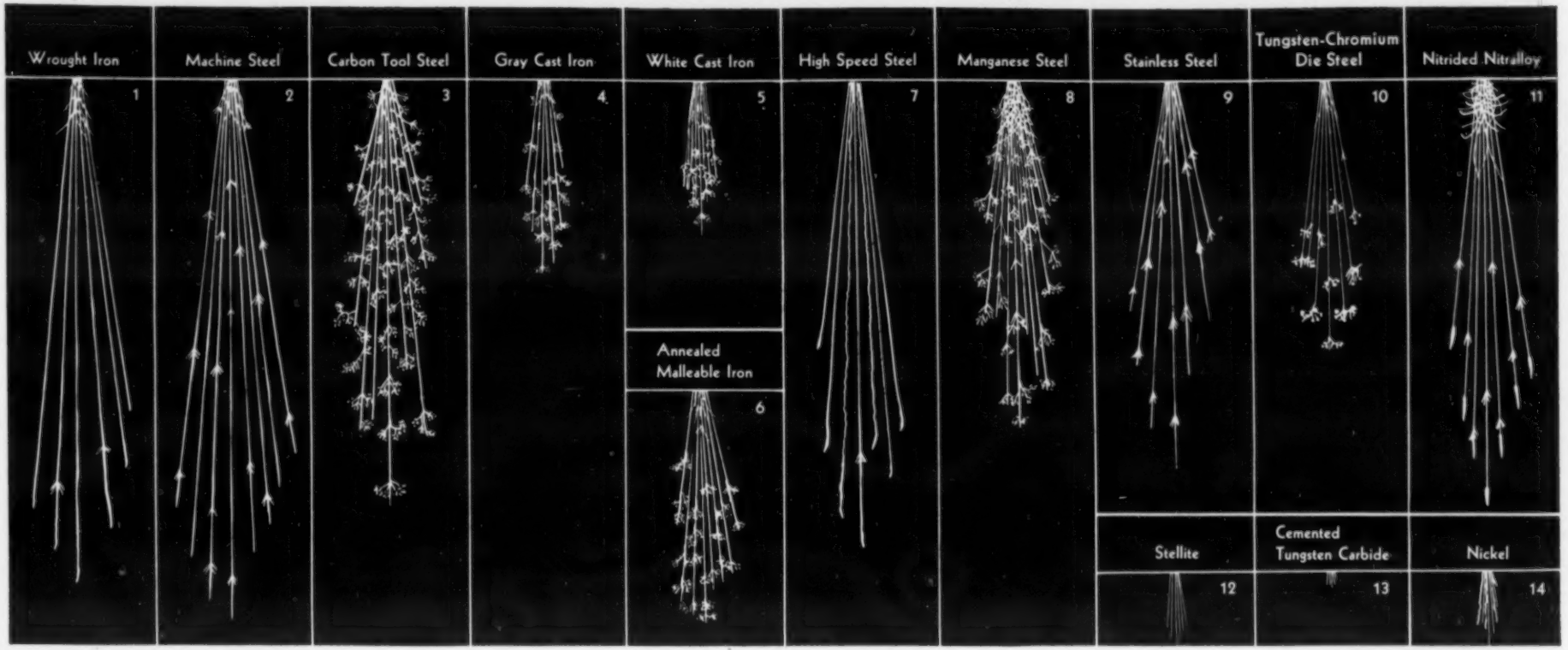


annual reference issue

october 1944

Spark Test for Metals

Reprinted from "Grits and Grinds" (Norton Co.), June 1940



Line	Metal	Volume of Stream	Length of Stream *(a)*	Color of Stream		Quantity of Spurts *(b)*	Nature of Spurts *(b)*	Line
				Close to Wheel	Near End			
1	Wrought iron	Large	65 in.	Straw	White	Very few	Forked	1
2	Machine steel	Large	70	White	White	Few	Forked	2
3	Carbon toolsteel	Moderately large	55	White	White	Very many	Fine, repeating	3
4	Gray cast iron	Small	25	Red	Straw	Many	Fine, repeating	4
5	White cast iron	Very small	20	Red	Straw	Few	Fine, repeating	5
6	Annealed malleable iron	Moderate	30	Red	Straw	Many	Fine, repeating	6
7	High speed steel	Small	60	Red	Straw	Extremely few	Forked	7
8	Manganese steel	Moderately large	45	White	White	Many	Fine, repeating	8
9	Stainless steel	Moderate	50	Straw	White	Moderate	Forked	9
10	Tungsten-chromium die steel	Small	35	Red	Straw *(c)*	Many	Fine, repeating *(c)*	10
11	Nitrided nitralloy	Large (curved)	55	White	White	Moderate	Forked	11
12	Stellite	Very small	10	Orange	Orange	None		12
13	Cemented tungsten carbide	Extremely small	2	Light orange	Light orange	None		13
14	Nickel	Very small *(d)*	10	Orange	Orange	None		14
15	Copper, brass, aluminum	None				None		15

(a) Figures obtained with 12-in. wheel on bench stand, and are relative only. Actual length in each instance will vary with grinding wheel and pressure.

(b) "Spurts" are the sparks (seemingly small explosions) that occur at intervals on the carrier lines.

(c) Spurts are blue-white.

(d) Some wavy streaks may be observed.

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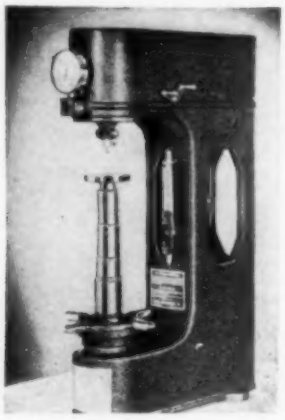

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Industrial baskets, crates, trays and fixtures. Rolock, Inc. Bulletin 204.

Handsome 12-page brochure pictures the cast steel breech rings and their advantages as produced by the Ohio Steel Foundry Co. Bulletin 515.

"Mechanical Springs, Their Engineering and Design" is the title of a 106-page handbook just issued jointly by the divisions of Associated Spring Corporation. Bulletin 481.

Many types of heat treating and pickling baskets and containers are shown in new booklet by the Stanwood Corp. Bulletin 445.

Specifications and diagrams are included in description of welded rings and bands. American Welding & Mfg. Co. Bulletin 536.

Complete line of Mallory radio, electrical and electronic parts, with sizes, dimensions and rated capacities is described in new 36-page booklet. P. R. Mallory & Co., Inc. Bulletin 448.

Use Handy Coupon on Page 652 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 652, 654, 656, 658, 660, 662, 664, 666, 668, 670, 672, 674, 676, 680, 681, 688, 892, 896, 897, 898, 988, 989 and 993.

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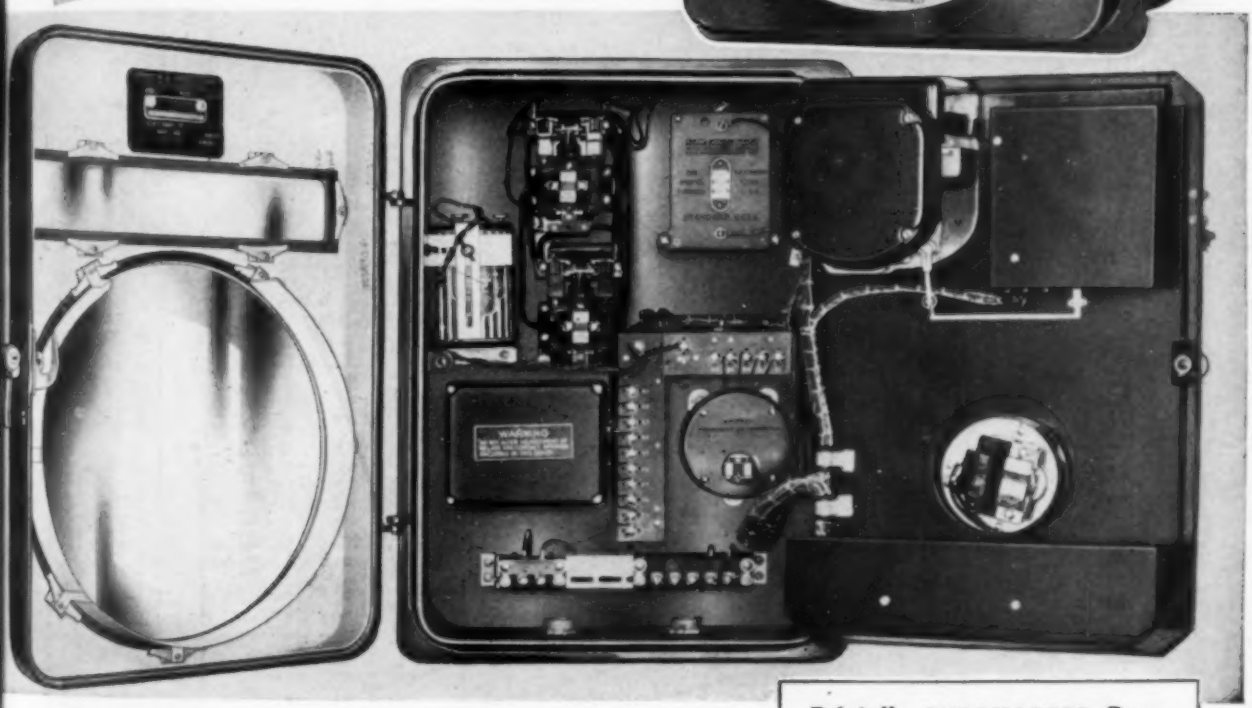

Pyromaster Pyrometer Electric-Type Controller, door open and panel swung out

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Exposure Chart for Radiography of Steel*

By Herbert R. Isenburger

BASED on the following combination: Pulsating direct-current tension generating equipment; line-focus X-ray tube; industrial intensifying screens; safety film; 5-min. development at 65° F.; film density 0.7.

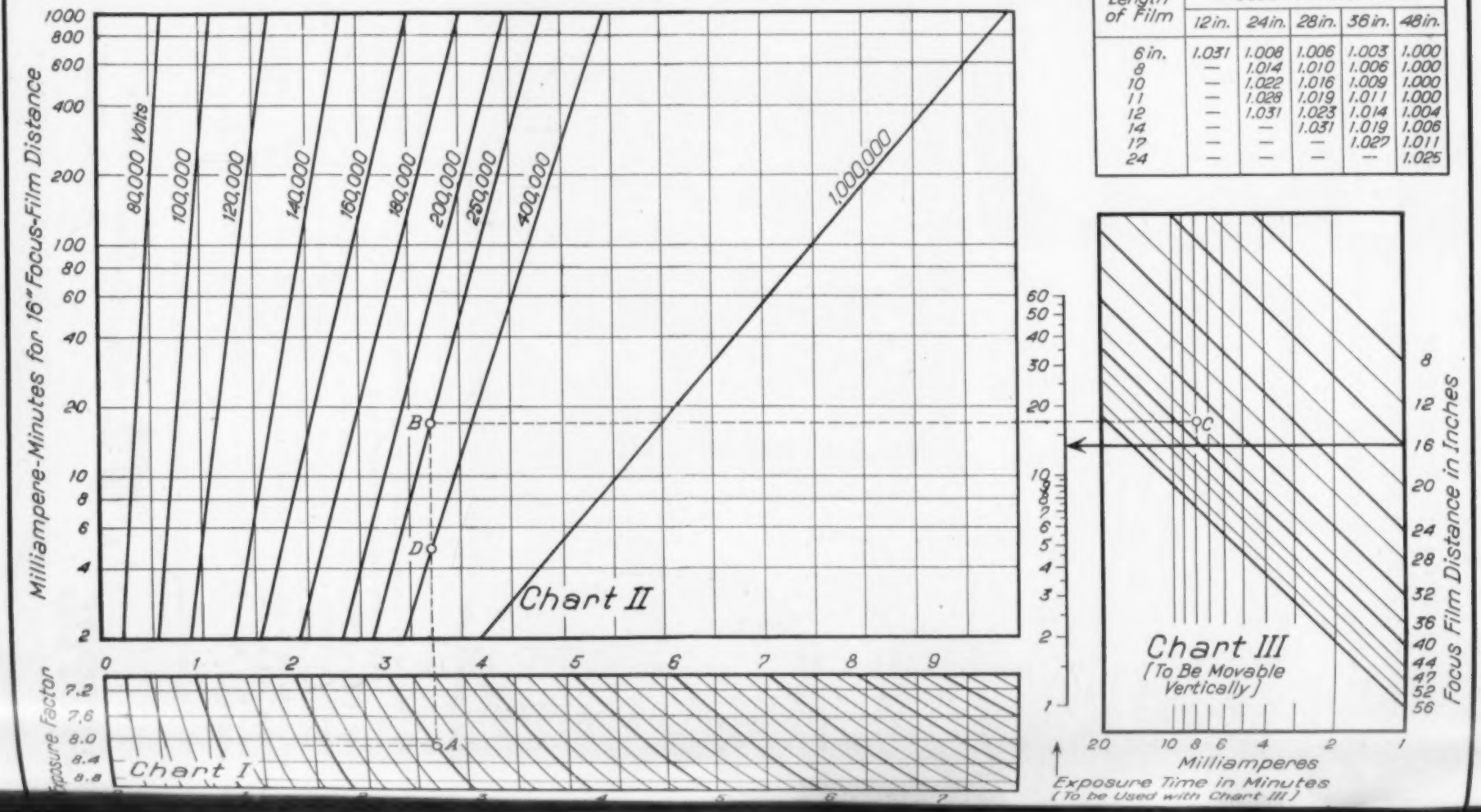
Required: Correct exposure on 17-in. film at 36-in. focus-film distance for 3-in. plate, density 7.85, using 250,000 volts and 8 milliamperes.

Solution: Multiply exposure factor 1.027 from the table by 7.85, density of the steel; the resulting exposure factor is 8.1. Find intersection of 8.1 with 3-in. line on Chart I (Point *A*), project upward to voltage of tube (Point *B* in Chart II). Adjust Chart III so that Point *C* (36-in. focus-film distance and 8 milliamperes) is opposite Point *B*, and exposure time is read on central scale against arrow: 13½ min.

Note: Scattered radiation must be filtered to get sharp definition above 250,000 volts, and filters increase exposures as follows: 10% for 1½ to 2 in. of steel, 20% for 2 to 3 in., 40% for 3 to 4 in., 50% for 4 to 5 in., and 75% above 5 in. If a 400,000-volt source were used in the above problem, adjust Point *C* opposite Point *D*; exposure time is 3½ min. without filter, which, increased 20%, comes to 4¼ min.

Table of Exposure Factors

Length of Film	Focus Film Distance				
	12 in.	24 in.	28 in.	36 in.	48 in.
6 in.	1.031	1.008	1.006	1.003	1.000
8	—	1.014	1.010	1.006	1.000
10	—	1.022	1.016	1.009	1.000
11	—	1.028	1.019	1.011	1.000
12	—	1.031	1.023	1.014	1.004
14	—	—	1.031	1.019	1.006
17	—	—	—	1.027	1.011
24	—	—	—	—	1.025

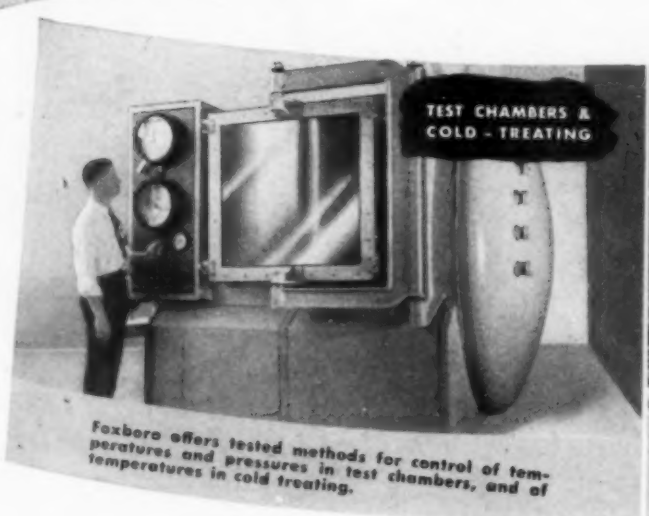


Controls

IN THE METAL INDUSTRIES

Foxboro Potentiometer Controllers on heat-treating operations provide control-sensitivity within 1/10 of 1% of scale range.

Foxboro Potentiometer, Pneumatic or Relax Temperature Controllers insure greater uniformity of output.



Foxboro offers tested methods for control of temperatures and pressures in test chambers, and of temperatures in cold treating.

Foxboro Pneumatic Temperature Controllers prevent variations in finish . . . cut rejections and save plating salts.

Write for full details of cost-reducing Foxboro Instrumentation for any process in your plant. **The Foxboro Company, 52 Neponset Avenue, Foxboro, Mass., U. S. A.** Also Montreal, Canada. Branches in principal cities.

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INSTRUMENTS by FOXBORO

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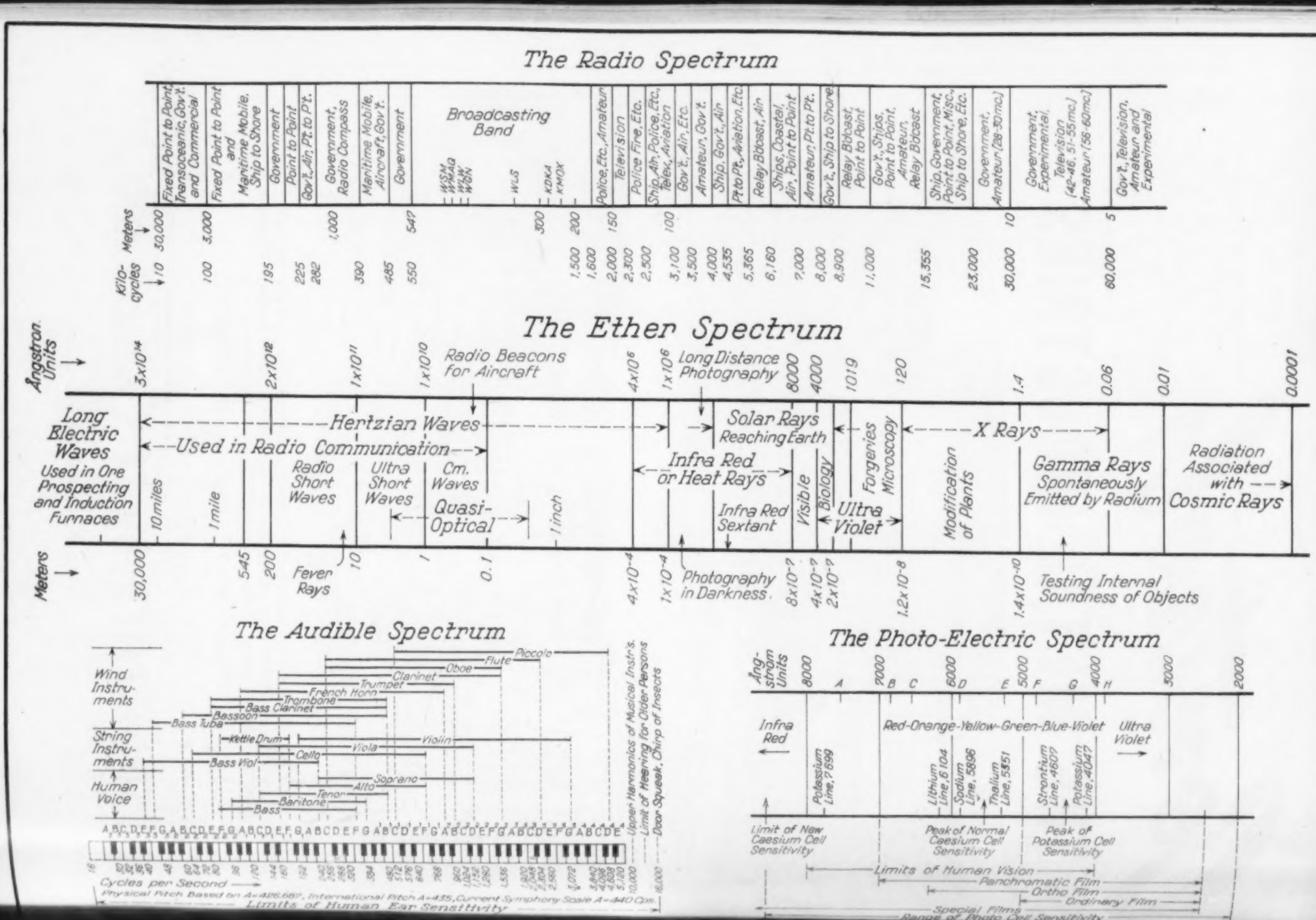
The Radio Spectrum
Meters
Kilo-cycles
Fixed Point to Point, Transoceanic, Gov't. and Commercial
Fixed Point to Point and Maritime Mobile, Ship to Shore
Government
Point to Point
Gov't, Air; Pt. to Pt.
Government, Radio Compass
Maritime Mobile, Aircraft, Gov't.
Government
Broadcasting Band
WISM WMAQ WLW WBN
WLS
KDKA
KMOX
Police, Etc., Amateur
Television
Police Fire, Etc.
Ship, Air, Police, Etc., Telex., Aviation
Gov't, Air, Etc.
Amateur, Gov't.
Ship, Gov't., Air
Pt to Pt., Aviation, Etc.
Relay Bdcast, Air
Ships, Coastal, Air, Point to Point
Amateur, Pt. to Pt.
Gov't, Ship to Shore
Relay Bdcast, Point to Point
Gov't, Ships, Point to Point, Amateur, Relay Bdcast
Ship, Government, Point to Point, Misc., Ship to Shore, Etc.
Government, Amateur, (28-30 mc.)
Government, Experimental, Television (42-46, 51-55 mc.) Amateur (56-60 mc.)
Gov't, Television, Amateur and Experimental
The Ether Spectrum
Angstron Units
Radio Beacons for Aircraft
Long Distance Photography
Long Electric Waves
Used in One Prospecting and Induction Furnaces
Hertzian Waves
Used in Radio Communication
Radio Short Waves
Ultra Short Waves
Cm. Waves
Quasi-Optical
Fever Rays
Infra Red or Heat Rays
Solar Rays Reaching Earth
Infra Red Sextant
Photography in Darkness
Visible
Biology
Ultra Violet
Forgeries
Microscopy
X Rays
Modification of Plants
Gamma Rays Spontaneously Emitted by Radium
Testing Internal Soundness of Objects
Radiation Associated with Cosmic Rays
The Audible Spectrum
Wind Instruments
String Instruments
Human Voice
Piccolo
Flute
Oboe
Clarinet
Trumpet
French Horn
Trombone
Bass Clarinet
Bassoon
Bass Tuba
Kettle Drum
Violin
Viola
Cello
Bass Viol
Soprano
Alto
Tenor
Baritone
Bass
Upper Harmonics of Musical Instrs.
Limit of Hearing for Older Persons
Door Squeak, Chirp of Insects
Cycles per Second
Physical Pitch Based on A=426.667, International Pitch A=435, Current Symphony Scale A=440 Cps.
Limits of Human Ear Sensitivity
The Photo-Electric Spectrum
Angstrom Units
Infra Red
Red-Orange-Yellow-Green-Blue-Violet
Ultra Violet
Potassium Line, 7699
Lithium Line, 6104
Sodium Line, 5896
Thalium Line, 5351
Strontium Line, 4607
Potassium Line, 4047
Limit of New Caesium Cell Sensitivity
Peak of Normal Caesium Cell Sensitivity
Peak of Potassium Cell Sensitivity
Limits of Human Vision
Panchromatic Film
Ortho Film
Ordinary Film
Special Films
Range of Photo Cell Sensitivity